TABLE D(i) Design standards (or codes) for pressure vessels

Country	National Pressure Vessel Code	Other Codes for Home Demand	Code Writing Body	Body responsible for Code Administration	Basis of Establishing Design Stress	Steels Acceptable for Code Construction		Mechanism for Acceptance of Steels	Legal Standing of National Code
						Designation	Standardising Body		
France	Réglementation des Appareils à Pression de Gaz (Unfired pressure vessels)	None except after modification, e.g. ASME in refineries	Syndicat National de Chaudronnerie et Tôlerie	Service des Mines	$R_t/3$	Steel complying with the following formulae is acceptable (a) $R_{20}\cdot d > 900$ where R_{20} is in kg/mm² and d is %age elongation (b) $d > 12\%$	Association Française de Normalisation Groupement des Associations de Propriétaires d'Appareils à Vapeur et Electriques Bureau de Normalisation de Sidérurgie	Steels are not required to be individually approved	Not a real code, no legal standing
Federal Republic of Germany	AD Merkblätter (Unfired pressure vessels)	ASME below 350 C	Technische Ueberwachungsvereine	TUV	Lowest of $E_t/1.5$, $S_R/1.5$, $S_r^*/1.5$	DIN and VDEh steels listed plus those individually approved by TUV	Deutsche Normenausschuss (DIN standards) and Verein Deutscher Eisenhüttenleute (VDEh)	Proprietary steels are submitted for approval to TUV and accepted on the basis of satisfactory mechanical test results	Force of law
Italy	ANCC Code	ASME	Associazione Nazionale Controllo Combustione (ANCC)	ANCC	$E_t/1.5$ or $S_R/1.5$	Boiler and Pressure Vessel plate to UNI, DIN and ASTM specifications are acceptable together with some designated proprietary steels from Italian Mills	Unificazione Italiana UNI	Steels are individually approved by ANCC	Force of law
Japan	Construction of unfired pressure vessels	ASME	Japanese Industrial Standards Committee	Industrial Manufacturers' Inspection Institute delegates authority	$E_t/1.7$ $E_t/1.5$ for Al	Steels complying with JIS standard	JIS	Steels are individually approved by JIS	No legal standing
Sweden	Tryckkärlsnormer (Pressure Vessels)		Swedish Pressure Vessel Commission	National Board of Workers Protection (WPB)	$E_t/1.5$ but t not less than 150°C	SIS steels listed in the Codes	Sveriges Standardiserings Kommission (SIS)	Steels listed plus those individually approved by WPB	No legal standing but mandatory in practice
United Kingdom	BS 1500	ASME Sec VIII	BSI	None. User or inspection agency is expected to supervise construction	$R_t/4$	Steels to BS specifications listed in code	British Standards Institution	A system for formal approval of materials is under consideration	Not legally mandatory but use regarded as established practice and could provide legal defence
	BS 1515				$R_{20}/2.35$ $E_t/1.5$ $S_R/1.5$ or $S_r/1.0$	Steels to BS specifications listed in code. Other steels provided that elongation is greater than 18% for plate and 15% for other forms			
United States of America	ASME Code Sec III (Nuclear vessels)	None	ASME	Inspection authorities of States and municipalities adopting code	$R_t/3$ or $E_t/1.5$	ASME specifications listed in code	ASTM/ASME	Steels standardised by ASTM are adopted by ASME perhaps slightly modified	Force of law where State has adopted code
	Section VIII				$R_t/4$, [illegible] or $E_t/1.6$				
International	Draft Boiler Code Pressure vessel code may be similar		ISO	National Inspecting Authority	$R_{20}/2.7$, $E_t/1.6$ $S_R/1.6$ or $S_r/1.0$	Registered national standards of ISO member countries	National standardising authority	National standards matching ISO may be registered with secretariat	Dependent entirely on national law

R_{20} — minimum ultimate tensile strength at room temperature

R_t — minimum ultimate tensile strength at operating temperature

E_t — minimum yield stress at operating temperature or if YS not clearly defined, 0.2% proof stress at operating temperature

S_R — average stress for rupture after 100,000 hours at operating temperature

S_r — average stress for 1% creep after 100,000 hours at operating temperature

S_r^* — average stress for 1% creep after 100,000 hours at operating temperature+15°C

Fig. F(1) Present status of PVRC projects 1967/68

MATERIALS DIVISION

Pressure Vessel Steels

Subcommittee formed during past year by merger of two previous groups. Pilot projects on heavy-section steels completed and published. Major program now under way on heavy-section steels. Project on fatigue of notched specimens finished. New project on effect of warm prestressing initiated.

Nuclear Applications

Expect to receive report "Effect of Irradiation on the Properties of Pressure Vessel Steels" this year. New areas to be covered are high strength steels for nuclear applications, operation at higher temperatures, and use of non-stress-relieved pressure vessels.

Hydrogen Embrittlement

Subcommittee now preparing Interpretive Report covering all latest available information.

Effective Utilisation of Yield Strength

New Subcommittee appointed during past year to develop and implement research program on significance of Y.S./T.S. ratio.

DESIGN DIVISION

Shells

Computer programs used to obtain design charts for torispherical and ellipsoidal heads. Heads under external pressure also being studied. Interpretive report published. New project on collapse of heads to be initiated.

Stresses in Ligaments

Program on stress concentrations in circumferential fillets completed. Work continuing on design procedures for flat plates and on analysis of thermal stresses in perforated plates.

Reinf. Openings & Ext. Loadings

Experimental investigations to continue at West. Res. Labs., Univ. of Waterloo, Univ. of Sherbrooke, and Univ. of Tenn. Theoretical analysis continuing. Evaluation program at BMI has resulted in six summary reports.

Bolted Flanged Connections

Subcommittee reviewed literature and conducted small analytical and experimental projects. Proposed design procedures developed and submitted to ASME. Work initiated on photoelastic analysis of flanges.

Stress Indices for Piping, Pumps and Valves

New committee has developed extensive research program to obtain information needed for forthcoming B31.7 Nuclear Piping Code.

FABRICATION DIVISION

Preheating & Postheating

Experimental program to determine effect of preheat and postheat on NDT temperature using "Delta Specimen" will continue.

Plastic Fatigue Strength

Fatigue tests completed on eight "full-size" vessels. Project on effect of mean stress completed. Program on cumulative damage will continue.

Therm. & Mech. Trtmts.

Long-range program to determine creep and stress rupture properties of pressure vessel steels in temperature range of 600–1,000° F completed. New project to start covering effect of treatments on fracture toughness of high-strength steels.

Weld Discontinuities

Subcommittee gathering information on effect of mechanical discontinuities associated with welds subjected to cyclic loading. To sponsor two reports.

APPENDIX E

General enquiry letter of 2nd February 1967

Purpose of the Letter

1 The Committe of Enquiry wished to seek views on a wide range of topics relating to the technology of pressure vessels including their standards, design and manufacture. To do this the Committee circulated a general letter of enquiry to a number of organisations, many of which were government departments, public bodies and representative associations, unions or institutions. Encouragement was given towards the preparatian of Submissions not only on the ten main areas noted below but on any other topics which respondents wished to bring to the attention of the Committee of Enquiry.

2 Altogether 77 organisations were circulated with the enquiry letter and suitable submissions solicited from these. Unsolicited contributions were also received from individual companies; these are not, however, included in the analysis of the response to the enquiry letter.

3 The number of replies to the enquiry letter is given in detail in Table E(1).

TABLE E(1)

Analysis of replies to enquiry letter of 2nd February 1967

Group	Letters sent	No reply	Replies	Of the replies; submission		
				declined	agreed	received
1. Govt. depts.	10	1	9	4	1	4
2. Public sector	15	0	15	6	0	9
3. Prof. instns.	14	1	13	5	2	6
4. Trades unions	6	2	4	2	0	2
5. Insurance bodies	8	0	8	4	0	4
6. Trade assocns.	24	1	23	3	2	18
TOTALS	77	5	72	24	5	43

4 There was a good level of preliminary response; 72 out of 77 organisations replied and they either:

declined to submit (24 organisations),

or agreed to submit, but had yet to submit (5 organisations),

or agreed to submit and had submitted (43 organisations).

5 A guide for the general reader's benefit has been prepared by making a numerical analysis of the replies to the enquiry letter and which indicates the frequency of comment on main areas of interest (or concern) to respondent organisations. This is shown

diagrammatically in the form of a bar chart in Fig. E(1), and covers the ten main areas of interest:

Design
Materials
Fabrication
Inspection
Insurance
Legislation
User requirements
UK industry
International practice
Background technology

as well as—Miscellaneous pressure vessels (dealing with problems relating to specific types of pressure vessel). The pattern of effort allocated by the Committee of Enquiry towards discussing these areas broadly followed the pattern of comment as shown in Fig. E(1). In undertaking its work the Committee naturally took into account the relative weighting of the respondents involved.

6 It is evident that the major problem areas were identified as those of design, inspection, materials, fabrication and background technology.

7 Fig. E(1) is, in effect, a summary bar chart of all sub-areas for each of the main areas. As 43 organisations had made submissions, the maximum 'number of respondents' possible for any of the Figs. E(2) to E(12) is also 43. Thus rationalisation of design standards was most frequent with 29 mentions (i.e. 68% of respondents), closely followed by rationalisation of manufacturing inspection with 28 mentions (i.e. 65% of respondents).

8 A detailed analysis for design is given in Fig. E(2) which shows that the question of rationalisation of standards was noted by nearly three times as many respondents as the next most frequently noted design sub-area. When considered with those noting rationalisation of standards preparation, this appears as the sub-area most frequently noted by respondents.

9 A detailed analysis for materials is given in Fig. E(3) in which rationalisation of steel specifications leads other sub-areas such as high temperature properties and cleanliness/quality control. It should be noted that these are views submitted by respondents in early 1967 and the position in respect of certain sub-areas may have altered by mid-1968, viz. steel specifications were being rationalised into a major series of BS, and its publication might now satisfy most of these respondents.

10 Fabrication does not throw up any outstanding sub-areas, see Fig. E(4), but the sub-area of Trades unions comes fairly low on the list, being noted by only four respondents.

11 Inspection shows a similar pattern to Design, see Fig. E(5), in that Rationalisation of manufacturing inspection is the most frequent sub-area by 50%. There is also a number of respondents noting the sub-area of certification of inspectors.

12 Fig. E(6) shows that Insurance was of less apparent interest than many of the other areas considered.

13 So also Fig. E(7) shows that legislation was noted less frequently, although there were certain aspects of legislation in the UK that caused respondents to note this sub-area.

14 User requirements in Fig. E(8) and UK industry in Fig. E(9) show respectively that User responsibilities including safety were major sub-areas, and that rationalisation of the UK industry and the import/export position were noted by a substantial number of respondents.

15 Fig. E(10) shows that many respondents felt the need for an ISO pressure vessel recommendation.

16 It is interesting to note that the sub-area—R & D (Communication to and use by fabricators)—headed the list of sub-areas in R & D, see Fig. E(11), over all other specific R & D topics.

17 A number of problems were noted by respondents in respect of particular types of pressure vessel. Fig. E(12) shows the relative frequency with which these are noted. The overall low numbers of respondents reflect the fact that this was not an area noted for comment in the general enquiry letter (in distinction to all the other areas considered above).

18 All of the individual replies from respondents were considered in detail by the Committee of Enquiry, and formed an important source of evidence. Whilst it is not possible to reproduce all of this evidence in this appendix, the Committee have taken into account all the important comments (made by respondents) in the text of the Chapters to this Report, and in the actions taken by the Committee subsequent to the receipt of the replies to the general enquiry letter (e.g. the materials surveys, the sub-committee on inspection, etc.).

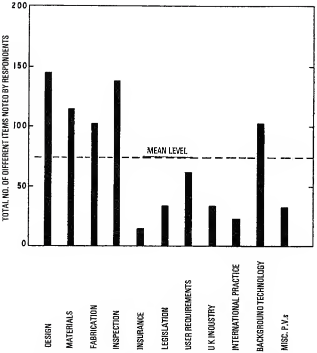


FIG. E(1). Division of comment from respondents by major areas

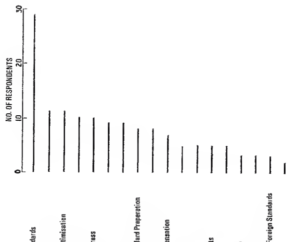


FIG. E(2). Detailed division of design items on which respondents commented

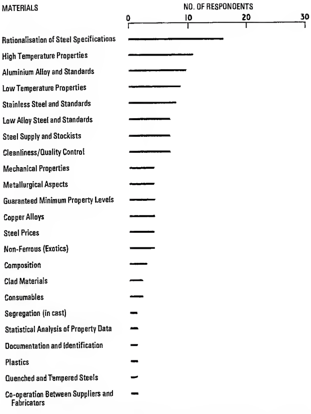


FIG. E(3). Detailed division of materials items on which respondents commented

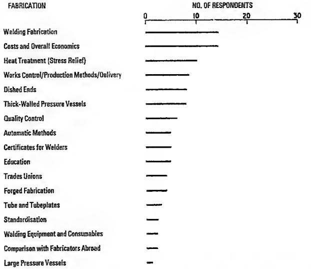


FIG. E(4). Detailed division of fabrication items on which respondents commented

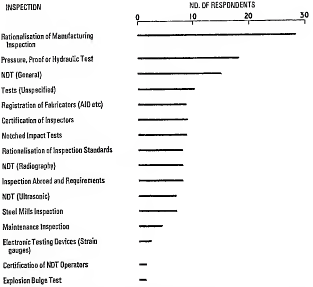
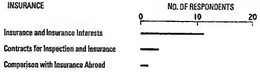
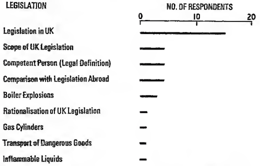


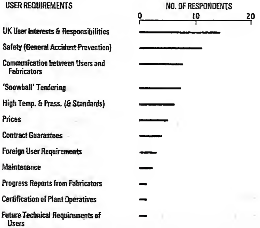
Fig. E(5). Detailed division of inspection items on which respondents commented



E(6)

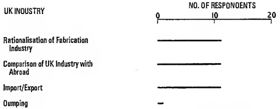


E(7)

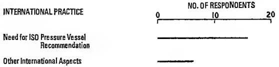


E(8)

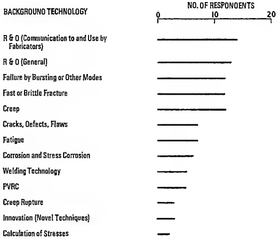
FIGS. E(6), E(7), and E(8). Detailed division of various items on which respondents commented



E(9)



E(10)



E(11)

FIGS. E(9), E(10), and E(11). Detailed division of various items on which respondents commented

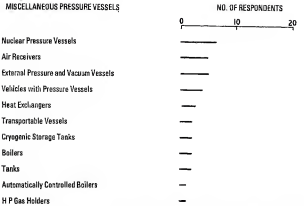


FIG. E(12). **Detailed division of various pressure vessels on which respondents commented**

APPENDIX F

Economic survey of the UK and selected foreign pressure vessel industries

prepared by

Dr. H. J. Ivey, Joint Secretary of the Committee of Enquiry, from research conducted in consultation with and on behalf of the Committee by

Battelle Memorial Institute
and
Ministry of Technology

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CHAPTER 1

Introduction

Objectives

1.1 The objectives of the economic survey have been to establish the following:

(a) the 'identification' of the UK pressure vessel industry (in terms of the total number of pressure vessel fabricators; their annual output of pressure vessels, heat exchangers and tanks; and the maximum 'spare capacity' in the UK that technically could be used for the manufacture of pressure vessels);

(b) the structure of the UK pressure vessel industry (in terms of its breakdown according to average size of company; specification with respect to vessel type—pressure vessels, heat exchangers or tanks; whether shop or site-built; materials used; maximum weights of vessel and thicknesses of plate material fabricated; and other relevant characteristics);

(c) the estimation of present and future demand for pressure and other vessels in the UK in the major user sectors;

(d) the level of imports of pressure and other vessels into the UK and the level of exports from the UK, including an estimated breakdown between exports via contractors and exports direct by the fabricators;

(e) the examination of the structure, output and competitiveness of the pressure vessel industries in the major competing countries: France, Federal Republic of Germany, Italy, Sweden and Japan;

(f) the estimation of present and future demand for pressure vessels in major foreign user sectors including: EEC, EFTA, COMECON, Latin America, India, Pakistan, and Japan;

(g) the approximate level of imports and exports of the major competing countries, thereby identifying the net importers and net exporters of vessels;

(h) the comparison of the UK and foreign pressure vessel industries, including an examination of technical, commercial and institutional factors influencing their relative competitiveness.

1.2 The above objectives are considered in the following Chapters and Annexes of the present economic survey [the letter sub-heads (a) to (h) correspond to those used in the above paragraph]:

(a) Chapters 2 and 7;
(b) Chapters 3 and 4; Annexes A, B, C, D and F;
(c) Chapters 5, 6, 7, 19; Annexes E, F and G;
(d) Chapters 6, 7, 8 and 9;
(e) Chapters 10, 11, 12; Annex H;
(f) Chapters 13, 14, 15, 16, 17, 19; Annex G;
(g) Chapter 10;
(h) Chapter 18.

Scope and methods

1.3 The survey has covered:

pressure vessels (built to a recognised design standard and subject to inspection);

shell and tube heat exchangers (built to a recognised design standard and with a shell thickness greater than ⅜" thickness);

plate welded tanks (capacity greater than 100 gallons and thickness greater than or equal to ⅜" thickness).

1.4 Pressure and other vessels are not readily definable products and due to lack of data in the Customs and Excise Import-Export Lists up to December, 1967, it was not possible to ascertain from available statistical sources:

the value of UK pressure and other vessel exports between 1962–1966;

the value of UK pressure and other vessel imports in the same period.

Because of this and other considerations it was not possible to obtain estimates of the balance of supply and demand in the UK.

1.5 The following approach for the economic survey was adopted:

(a) PRODUCTION of pressure vessels in the UK was obtained by circulation of questionnaires (over 1,200) to every company which was thought to have production facilities for pressure vessels;

(b) PRESSURE VESSEL PRODUCTION CAPACITY was calculated on the basis of the sum of fabricators' estimates (returned in the questionnaires) of how much more they could have produced *with the same equipment* and labour situation, but continuing with the same volume of known pressure vessel work;

(c) UK DEMAND for pressure vessels was estimated for the four main demand sectors:

Gas: estimates of purchases from 1962–3 to 1967–8, with forecasts up to 1972–3 under the industry's five year development plan, were obtained from information supplied by the Gas Council and Area Boards;

Electricity: the CEGB and the SSEB provided estimates of purchases up to 1970–1 under the approved building programme (excluding Hartlepool); methods were also derived for relating vessel purchases to the total cost or Megawatt capacity of stations likely to be approved in future;

Oil: estimates of purchases were made by applying pressure vessel ratios either to the industry's investment in refinery plant or to its total purchases of hardware (given in the 3rd report of the Process Plant Working Party);

Chemicals: two separate sets of estimates were made: the first came from the application of vessel ratio to estimated expenditure on equipment in the relevant sectors of the industry, and the second came from a CIA sample survey of its members, asking for purchases of vessels made by them or on their behalf from 1962–67. (It was not possible to obtain estimates of purchases by the contractors.) These two methods are described further in paragraphs 1.13 and 1.14.

(d) IMPORTS it was not possible to obtain figures of imports, apart from the estimates included in the CIA survey which are not thought to reflect accurately imports of the whole industry;

(e) DIRECT EXPORTS of pressure vessels were obtained from fabricators' returns. It was not possible to obtain (from contractors) estimates of the much larger volume of vessels exported through such organisations.

1.6 *The supply survey* in the United Kingdom was directed towards actual or possible pressure vessel fabricators culled from lists obtained from:

organisations such as the Tank and Industrial Plant Association and the British Chemical Plant Manufacturers' Association that both had membership lists that could serve as a basis for identifying the pressure vessel industry;

very complete lists, drawn up by Battelle and the Ministry of Technology, of companies in the United Kingdom who were thought to have the fabrication facilities necessary for the manufacture of pressure vessels.

1.7 Two basic questionnaires were used: a long one to provide details on companies which were thought to be significant pressure vessel manufacturers; and a short one sent to a large number of companies to provide for complete coverage of output. The long questionnaire was initially sent out as a pilot questionnaire and then revised slightly for a further limited circulation (as the long questionnaire). The questionnaires were designed to define:

the type of fabricator;

the main production range and product specialisation;

the factors limiting capacity;

the use of the labour force;

the allocation of man-power;

details of heavy fabrication facilities and equipment;

the significance, profitability and duration of activity as a pressure vessel builder;

production statistics (output for 1966 and orders received 1962–1966).

1.8 High response rates of 80% or more were received in reply to these questionnaires, but not many companies were able or willing to provide details of statistics of orders received before 1965. This meant that the fluctuations in output before 1965 and 1966 could not be defined with any accuracy, as the returns of total orders were usually linked to the total output of the heavy fabrication shop and not just to pressure vessels. A pressure vessel percentage can be calculated from this by using the respondents' indication of the significance of pressure vessels but this was not particularly accurate.

1.9 The short questionnaire provided information on the 'tail' of the pressure vessel industry and was designed to:

identify all other fabricators;

determine their category or activity;

produce essential information on capacity, output and the profitability of manufacturing pressure vessels.

1.10 All these questionnaires were broken down and analysed in various ways and constitute the basis of Chapters 2 and 3, and Annex B.

1.11 In the course of the survey interviews were held with thirty-five fabricators to obtain an understanding of the problems facing the pressure vessel industry, and the causes of and possible solutions to these problems. These interviews were designed to augment the data acquired from the questionnaires and to provide qualitative information on the structure of the industry, management attitudes, production equipment, labour availability and labour relations, market orientation, marketing methods, and the numerous other factors which determine the competitiveness of a particular industrial sector.

1.12 *The demand survey* included interviews undertaken with the essential demand elements—the contractors and the final users—to obtain their comments on the UK pressure vessel industry, their criteria of choice and purchasing methods, and the reasons why pressure vessels had been imported. It also provided an outline of the types of pressure vessels used in each main demand sector and to indicate future requirements.

1.13 *The demand survey* in respect of the chemical industry was undertaken in the following manner. The twenty most important chemical contractors (or contracting divisions of major plant users) in the United Kingdom procure about 50–70% of all chemical plant in the UK, and although they are essentially intermediaries in the demand pattern and not generators of demand, without their records any economic survey on chemical plant would not be feasible. In the course of this survey, despite a number of approaches, only two-thirds of the contractors were able or disposed to prepare a simple return on pressure vessels, although all were co-operative in providing valuable qualitative comment on how they, as contractors, viewed the British vessel industry. An estimate had, therefore, to be made of the percentage coverage represented by the British contracting industry in terms of value of equipment procured, both for home and overseas projects.

1.14 The following two approaches for the chemical industry demand survey were adopted:

(a) The chemical industry was divided into its main product components in greater detail than that established under the SIC minimum list headings. Investment figures (essentially expenditure on plant and machinery) were sought for each list heading. It was intended to apply an appropriate pressure vessel ratio to each sub-sector, derived from the figures for actual plants obtained from field interviews. However, a long series of investment figures in this detail was not obtainable, for the Board of Trade's Census of Production figures were not continuous, and the annual investment figures published did not go to sub-sector level for the chemical industry. Neither were investment figures held by the various trade associations for companies in the industry. The following approach was adopted in order to allocate investment figures for sub-sectors of this industry. In its annual surveys of the chemical industry, 'Chemical Age' gives estimates of expenditure on plant for each sector of the chemical industry and the figures are thought to provide a reliable guide to the division of investment between heavy organics, inorganics, fertilisers and so on. For this survey, therefore, the official total investment figure for the chemical industry has been divided between the sectors of the industry according to the percentage division in the 'Chemical Age' surveys. It is to these proportions of the total investment figures that the appropriate pressure vessel ratios have been applied.

(b) The above method for the chemical industry was cross-checked by the circulation of questionnaires by the Chemical Industries Association on the survey's behalf to a sample of twenty-six chemical companies, all of which were returned.

The results of methods (a) and (b) tally reasonably well, and whilst accepting the inevitable limitations of these methods, they have also provided a way of evaluating pressure vessel demand per sub-sector of the chemical industry.

1.15 The evidence and opinions of a large number of organisations and personnel were noted in the course of the survey, and the types of organisation interviewed are indicated below (the numbers of corresponding interviews are shown in brackets):

Government organisations (3)
Organisations concerned with design standards and inspection (2)
Trade associations (6)
Research associations (2)
Nationalised industries (3)
Pressure vessel fabricators (34)
Forge masters (6)
Steel plate suppliers (3)
Chemical engineering contractors (21)
Pressure vessel users (35)
Export promotion organisations (3)

1.16 It was considered desirable to examine the pressure vessel industries of France, Germany, Italy and Sweden together with that of Japan (whose presence of massive integrated steel producing, fabricating and contracting groups in international markets is believed to be significant). The approach for countries abroad was as follows:

national and relevant trade association statistics were acquired and analysed. The detailed breakdown with regard to product categories was, as with the United Kingdom, not entirely satisfactory;

the main foreign pressure vessel fabricators were identified and their brochures and annual reports obtained;

interviews were, where possible, held with:

- the association(s) grouping the sections of heavy fabrication industry in which pressure vessel fabricators were to be found;
- the official design standards and inspection authorities;
- three to four chemical contractors;
- three to four main final users;
- three to five pressure vessel fabricators;
- a major steel plate supplier.

1.17 The various sources and interviews outlined above made it possible to establish 'profiles' of the relevant foreign industries; this also provided a basis for comparison with the UK industry.

Definitions

1.18 Definitions used in the economic survey of the UK pressure vessel industry are as follows:

PRESSURE VESSELS are vessels built to a recognised British or foreign design standard and/or subject to inspection requirements;

HEAT EXCHANGERS are *only* those of the shell and tube type with a shell thickness greater than ⅜″, and built to a recognised design standard;

TANKS are storage vessels, bulk transport containers etc., or other vessels with a capacity of more than 100 gallons, made from plate not less than ⅜″ in thickness and of welded construction (includes fixed tanks, road and rail tankers and demountable tanks, e.g. for carriage by ship, road or rail).

1.19 Throughout this report whenever 'pressure vessels' is implied as a generic term meaning 'pressure vessels, heat exchangers and tanks', the generic term *used* is 'vessels'. Thus 'vessels' are receptacles, usually manufactured by welding metal plate, containing fluid under pressure or vacuum, of the pressure vessel, heat exchangers and tank types.

1.20 Vessels need to fulfil certain safety requirements as failure can result in explosion or the loss of dangerous fluid. Vessels are, therefore, nearly always constructed to a design standard or 'code' which incorporate safety aspects of design and construction and good design practice. This permits a precise definition of a pressure vessel, viz., 'all vessels built to a pressure vessel design standard and/or subject to inspection requirements'. The standards are usually BS 1500 and BS 1515 in the UK, ASME Sections III and VIII in the USA, and the various publications under the auspices of TUV in Germany.

1.21 These design standards may be used for the construction of various plant items including:

storage vessels, which may be used for storage of gases: nitrogen, carbon dioxide, air, chlorine etc., and these 'gases' may be liquefied. Town-gas, petroleum and many chemical products are also frequently stored under pressure at various stages of production. In storage vessels simple physical processes, notably mixing and heating, may take place. 'Spheres' are examples of very large storage vessels;

reactor vessels are generally associated with higher pressure, temperature and corrosion conditions than storage vessels. These vessels may vary from the huge hydrogenerator vessel of an oil refinery, to the shell of a shell boiler, or a small reactor vessel for dyestuffs;

columns, often used in the petroleum and petrochemical industries, include distillation and scrubbing columns, and are amongst the largest pressure vessels built;

heat exchangers of the sbell and tube type frequently support a pressure on the shell side and may be considered as 'pressure vessels'. When the generic term 'vessels' is used in this report with no separate mention of heat exchangers, heat exchangers fulfilling these conditions are included;

tanks could well be defined as non-pressurised vessels and are used for storage of liquids, such as fuel oil, at near atmospheric pressure. However, pressure vessel design principles are usually used for large tanks. They have been included in the generic term 'vessels' in the same way as heat exchangers.

1.22 The units used in the economic survey are defined as follows:

weights	all tonnages referring to the UK are long tons, whereas metric tons are used for the Continental industries. The difference in the context of this survey is not significant;

pressures	these are invariably referred to in pounds per square inch gauge (psig);
value of £	the pound sterling referred to throughout is that *prior* to the 18th November 1967 devaluation (i.e. $2:80 to the £1);
temperature	the centigrade scale has been used throughout;
prices (foreign)	all basic historic data on *FOREIGN* supply, demand and investment are quoted at their (historic) contemporary prices. All estimates of demand in the future are quoted at 1966 price levels, but these future estimates do include a factor allowing for the steady inflation of (cash) prices, since the future estimates made are based on an historic series of steadily increasing *and* inflating prices;
prices (UK)	all basic historic data on *UK* supply, demand and investment are quoted at 1966 price levels (obtained by use of appropriate price indices). All future estimates are given strictly at 1966 price levels (i.e. unadjusted for any inflation).

1.23 For a full list of definitions of other terms used in the economic survey, the reader is referred to Appendix C—'Glossary of technical and industrial terms' given in Volume 1 of the Report of the Committee of Enquiry on Pressure Vessels.

Acknowledgements

1.24 The economic survey team would like to extend its appreciation to all those organisations and individuals who, through so freely giving their time and experience, had made the economic survey on pressure vessels possible. All the organisations, and the many companies responding to the various questionnaires, had made helpful and valuable contributions. Whilst it would be unfair to single out particular organisations and individuals for special mention, the economic survey team wishes to express its sincere thanks to all concerned.

CHAPTER 2

UK supply: output and capacity

The postal survey

2.1 This chapter outlines the output and capacity of the UK pressure vessel industry. It is based mainly on the postal survey (pilot, short and revised long questionnaires taken together) but for some points of interpretation draws on the results of the interviewing programme. Details of the numbers of questionnaires sent out and returned are as follows.

2.2 The master list of UK companies that might fabricate pressure vessels was compiled from the following sources:

companies returning output of pressure vessels and related products in the 1963 Census of Production;

companies returning output of mechanical and electrical engineering products under the following statistical headings (Ministry of Technology):

19 Water-tube boilers
20 Shell boilers and boiler-house plant
21 Chemical plant
22 Iron, steel and non-ferrous metal works plants, other than rolling mills
23 Other industrial plant and fabricated steel-work;

Kompass trade directory;

lists from trade associations (TIPA and BCPMA);

Lloyds list of registered Class 1 fabricators;

miscellaneous (trade journals, personal contacts, etc.)

2.3 Three questionnaires were prepared, and the numbers sent and returned were as follows:

(a) pilot questionnaire, sent to a random sample of 50 companies (constant sampling fraction) and a selection of the companies interviewed in August, 1967:

Number sent	61		
Returns	50 (82%) of which:	Positive	27
		Negative	23

(b) revised long questionnaire (sent to a purposive selection of important pressure vessel fabricators).

Number sent	29
Returns	24 (83%, all positive)

(c) Short questionnaire (sent to the rest of the companies on the master list).

Number sent	1,043		
Returns	912 (88%) of which:	Positive	215
		Negative	697

'Positive' returns were defined as those from companies that had made pressure vessels within part or all of the period 1961–66 (not all necessarily had any output of pressure vessels in 1966).

2.4 Two important points should be noted in regard to interpreting the tables and figures:

the survey has effectively taken a 'snapshot' of the industry during one year only (1966). There is no means of knowing what differences in the pattern there would be if another year were taken;

the tables and figures necessarily relate only to the companies that returned questionnaires and were able to give the relevant information. The number of returns included therefore varies between analyses of individual aspects but in general the analyses are based on actual returns from companies estimated to account for between 70% and 90% of pressure vessel output in 1966.

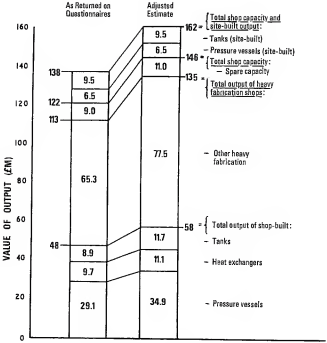
UK pressure vessel output: 1966

2.5 Fig. 2(1) gives the industry's output and capacity as returned on the questionnaires together with estimates for the industry as a whole. The same data is also given in Table 2(1) in view of its importance for the economic survey.

TABLE 2(1)

Output and capacity of the UK pressure vessel industry, 1966 (£M)

	As returned on questionnaires	Percentage additions	Adjusted estimate
SHOP-BUILT OUTPUT	£M		£M
Pressure vessels	29·1	+20%	34·9
Heat exchangers	9·7	+14%	11·1
Tanks	8·9	+31%	11·7
	47·7	+21%	57·7
Other heavy fabrication	65·3	+19%	77·5
Total output, heavy fabrication shop	113·0	+20%	135·2
Spare capacity	9	+22%	11
TOTAL SHOP CAPACITY	122	+20%	146
SITE-BUILT			
Pressure vessels	6·5	+ 0%	6·5
Tanks	9·5	+ 0%	9·5
	16·0	+ 0%	16·0



(Note: The figures in the second column are weighted to allow for non-response and for 28 fabricators who were unable to give the value of their output in 1966. It is thought that the major companies specialising in site-work all returned questionnaires and these figures have not been adjusted.)

FIG. 2(1). Estimated output and capacity of the UK pressure vessel industry 1966

Procedures to obtain adjusted estimates for output data

2.6 The weighting procedure used to allow for non-response and fabricators unable to give output figures is as follows.

2.7 The outputs of pressure vessels, heat exchangers and tanks were adjusted according to the source of the 'as-returned' data. Thus for the pilot and revised long questionnaires:

for the large companies not replying, individual estimates of output were made,

for some of the smaller companies enough information was available for individual estimates also to be made,

for the remainder, average output figures were applied, based on the total number of 238 fabricators who replied and were able to give output figures.

For the short questionnaires, the pressure vessel average regional output figures were obtained from the positive replies and applied to companies unable to give output figures and to the estimated numbers of fabricators among non-respondents. The details are shown below:

	Total non-respondents	Estimated no. of fabricators in non-respondents	Respondent companies but with unknown output	Total no. of companies to be added	Average output of respondent companies —£'000	Total regional allowance added —£M
		(a)	(b)	(a+b)	(c)	(a+b)×c
Scotland	19	4	7	11	51	0·6
Northern	11	2	—	2	25	0·1
North West	27	6	1	7	59	0·4
Yorkshire and Humberside	11	3	4	7	59	0·4
East Midlands	8	2	1	3	29	0·1
West Midlands	20	4	5	9	51	0·5
Wales	1	—	—	—	30	—
East Anglia	3	1	2	3	57	0·2
South East	31	5	4	9	75	0·7
South West	—	—	2	2	30	0·1
Northern Ireland	—	—	—	—	—	—
UNITED KINGDOM	131	27	26	53	57	3·1

Also for the short questionnaire, the tank and heat exchanger average output figures were obtained for the 189 fabricators who replied and were able to give output figures. These were then applied to the estimated number of non-respondent fabricators and to the fabricators who replied but were unable to give figures. The assumption was also made that the output figures for pressure vessels, heat exchangers and tanks given in the short questionnaires all related to shop-built output; as no distinction was made in the short questionnaires between shop- and site-work. The shop-built figures therefore are likely to contain an element of site-work, but this is thought to be insignificant.

2.8 The total output from the heavy fabrication shop was obtained as follows. For fabricators able to give pressure vessel output figures, but not the output of the whole shop, average shop output figures were used based on pressure vessel output groupings. Nearly all the fabricators returning the short questionnaire were in pressure vessel output groups I and II, and a combined average shop output figure for these groups was used for other fabricators returning short questionnaires (nil or unknown vessel output) and for the estimated number of non-respondent fabricators. For fabricators not returning the pilot and revised long questionnaire average output figures were used based on the total number of fabricator returns in the survey as a whole. For a definition of output groups I and II see paragraph 3.6.

Accuracy of the output data

2.9 It is not possible to say precisely what is the error in these data. Some fabricators will have been omitted altogether from the lists used in the survey and there is no means of estimating how important such a short-fall may be. It should be noted, however, that more small companies than large ones are likely to have been omitted. Moreover, any short-fall in the figures is likely to be larger for tanks and heat exchangers than it is for pressure vessels for the following three reasons:

while a comprehensive coverage of heavy fabrication shops was attempted, the whole emphasis in the survey, and the accompanying publicity, was in locating pressure vessel producers;

questions 1 and 2 in the questionnaires will have eliminated from the survey all companies not producing vessels in the period 1961–66;

the incentive to reply was not so great for tank and heat exchanger specialists as it was for pressure vessel producers; the weighting procedure used assumed broadly that the same proportions of non-respondents produced vessels, heat exchangers and tanks as was respectively the case for the respondents, and that their average output of these products would be the same as for respondents; this could be an over-estimate for pressure vessel producers and an under-estimate for tank and heat exchanger fabricators.

2.10 There is a second source of error contained in the questionnaires themselves. Many of the output figures given are estimates and it is impossible to know how accurate companies' estimates have been, although a proportion of the errors will be self-cancelling. Some large companies could only indicate the range within which their output fell and for them the mid-points of the ranges have been taken. For some other large companies who returned incomplete questionnaires or made no return at all, estimates of output have been made based on other information about these companies.

2.11 Thus the output estimates are liable to a substantial error, at least ±10% for pressure vessels and greater for the other categories. The figures for pressure vessel output are likely to approximate to the true industry total, but for tanks, heat exchangers and the heavy fabrication shop as a whole should be regarded only as estimates of output in these categories in 1966 *by pressure vessel producers*. The extent to which they represent industry totals will depend on the importance (which we do not know) of pressure vessel producers in each of these output categories.

Numbers of fabricators and potential fabricators in 1966

2.12 The numbers of pressure vessel, tank and heat exchanger fabricators revealed by the survey confirm that the returns essentially give a picture of the *pressure vessel* industry. Of the 266 companies making positive returns (i.e. companies that had made pressure vessels in the period 1961–66):

242 (91%) had some output of pressure vessels in 1966,

187 (71%) are thought to have had some output of tanks in 1966,

123 (46%) are thought to have had some output of heat exchangers in 1966.

2.13 Of the companies returning questionnaires that said they had not made vessels in the period 1961–66, 125 had a heavy fabrication shop which they considered suitable for producing vessels. When this figure is taken together with the estimates of the number of fabricators who failed to reply to the survey the conclusions are:

there were some 310 pressure vessel fabricators in the UK in 1966, of whom some 90% had vessel orders;

a further 125–150 companies considered that they had production facilities suitable for vessels but had shown no interest in the market for some years.

Trends in the number of pressure vessel fabricators

2.14 The above numbers are estimates for 1966. The factors illustrating the *trend* in the number of fabricators are as indicated in the following two paragraphs.

2.15 Table 3(2) shows that about a fifth of those returning the questionnaires had come into the industry in the 'sixties'. These were predominantly small producers in 1966; most of the large fabricators in that year had been in the industry for at least 20 years. The same table shows that only 3% of fabricators plan a future decline in pressure vessel output, while three-quarters hope their output will increase. Taken together, these figures suggest that the number of fabricators is increasing fairly rapidly.

2.16 Further evidence of the growing number of fabricators came from the interviewing programme. Several new entrants were seen, both large and small; these were medium and heavy engineering companies whose traditional business had declined or vanished (structural steelwork, boilers, gas holders, tar stills, water filter shelves), or had been taken over by their clients (car radiators) or simply become more competitive (heat exchangers). Other companies still had spare capacity in fabrication shops set up to supply platework for their machinery products. All these had entered the pressure vessel field because they considered it was a growth market.

The capacity of existing fabricators

2.17 A further process of diversification and change was going on within the pressure vessel market itself. The great importance of a few clients and a few industries in this field, all with spasmodic buying programmes, meant there were sharp fluctuations in the types of vessels wanted as well as in the total volume of orders. Several companies visited had at one time relied largely on the Gas Council or the Central Electricity Generating Board for their business and were in great difficulties when, for example, expenditure on gas reforming plants or nuclear power stations ceased or came to a temporary halt. Some of the companies visited had been through very bad periods in which they had nearly gone into liquidation, and some were continuing in poor straits.

As a result, companies were found diversifying from heat exchangers into pressure vessels and from pressure vessels into heat exchangers; from mild steel to special steels and from special steels to mild steel; from medium to heavy vessels and from heavy to medium: in each case on the grounds that the prospects in the new field were better than those in their existing field.

2.18 As part of this process of diversification, some fabricators were expanding their production capacity by reorganisation, adding new machines or even building new shops.

2.19 Other important factors affecting pressure vessel fabricators' capacity were the trends in demand for their other products, which in 1966 accounted for about half of their shop output. Figure 2(2) gives fabricators' commitment to the other products listed on page 1 of the questionnaires, bringing out the importance of tanks, boilers, furnaces and kilns, iron and steel works plant, mining equipment and other, unspecified types of plate-work. Some of the listed products are known to have had declining prospects in recent years (boilerwork, atmospheric pressure gas holders, shipbuilding). For interest, the available output figures are given in Table 2(2) where it can be seen that, apart from switch-gear and control-gear, all the products listed had a fairly sluggish sales trend in the period 1960–64.

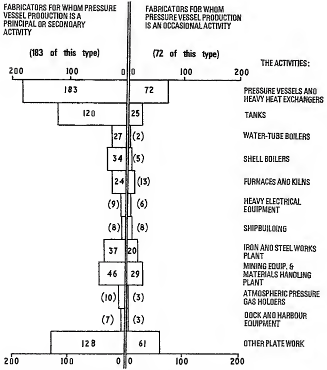


FIG. 2(2). Numbers of pressure vessel fabricators recording other products as a principal or secondary activity in their heavy fabrication shops

TABLE 2(2)

Total UK deliveries of heavy fabrication work at current prices

	Mining machinery		Mechanical handling equipment		Water-tube boilers	
	£M	Index	£M	Index	£M	Index
1960	46·0	100	86·9	100	57·2	100
1961	53·6	117	97·5	112	56·4	99
1962	49·7	108	107·2	124	63·4	111
1963	52·8	115	102·6	118	59·3	104
1964	56·3	121	110·3	116	63·1	110
1965	54·9	119	118·3	136	81·2	142
1966	61·2	133	132·5	153	91·7	160
1967 (prov.)	69·8	152	130·9	151	86·5	151

	Shell boilers and boilerhouse plant		Iron, steel and non-ferrous metal works plant(excl. rollingmills)		Generating plant and rotating electrical machinery	
	£M	Index	£M	Index	£M	Index
1960	30·8	100	26·3	100	134·2	100
1961	32·6	106	34·1	130	140·6	105
1962	31·3	102	31·1	118	141·5	105
1963	31·0	101	29·3	111	135·9	101
1964	32·6	106	37·6	143	138·5	103
1965	36·3	118	34·3	130	147·0	110
1966	48·1	156	36·7	139	156·0	116
1967 (prov.)	47·1	153	37·1	141	160·6	120

	Transformers for lighting, heating and power		Switchgear and control gear	
	£M	Index	£M	Index
1960	43·0	100	115·8	100
1961	48·5	113	131·1	113
1962	53·8	125	134·1	116
1963	54·6	127	137·2	119
1964	64·5	150	155·9	135
1965	65·7	153	172·9	149
1966	69·1	161	197·9	171
1967 (prov.)	62·7	146	199·5	172

2.20 The interviewing programme and the results of Table 3(2) confirm that many companies were pinning their hopes on pressure vessels rather than alternative products. While unable to achieve reasonable current levels of orders or profits, or to see an improvement in their situation in the short-term, many companies took the view that pressure vessels, being tied so closely to the fast-growing chemicals industry, must be the most promising fabrication product. Some other companies, however, considered that better prospects lay with high technology products, whether in the pressure vessel field or outside it, and some of these specifically hoped they would find market opportunities of this type outside the pressure vessel field, with its fluctuating order pattern and surplus manufacturing capacity. These tended to be the larger and more sophisticated companies.

2.21 Finally, capacity was affected by the productivity of the men and machines employed in the industry. It is simply noted here that the results of the survey suggested both that there is scope for raising further the productivity of certain British fabricators and that some fabricators were now undertaking measures which should improve their productivity and shop throughput times

Conclusions on output and capacity

2.22 The trend that emereged was of a growing number of relatively small producers of pressure vessels, each trying to achieve some security by making a fairly wide range of products. This was possibly more important in the overall market situation than the opposing trend to specialisation which was found in some companies. Such companies specialised by concentrating on a narrow range of products so as to cut costs and increase competitiveness. Flexibility or diversification of some kind was an inevitable answer to uncertain and fluctuating markets. The important questions are whether the companies in the industry are likely to be economically or technically viable units; whether there is scope or need for further specialisation; and whether capacity for high technology vessels is adequate.

2.23 The survey strongly suggests that for some time capacity has been growing faster than demand. Table 3(2) shows wide dissatisfaction with recent profit levels, particularly among the larger companies. Many long-established fabricators visited complained of a drastically falling profit trend, levels of 10–20% in the 'fifties being compared with low or non-existent profits in the 'sixties. These complaints were made about heat exchangers and both mild steel and special vessels.

CHAPTER 3

UK supply: structure

The regional distribution of vessel output

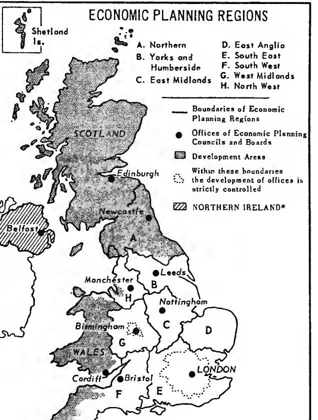
3.1 The regional distribution of output has been estimated for shop-built pressure vessels and the figures are summarised below:

Estimated regional distribution of shop-built pressure vessel output, 1966

	Number of fabricators		Output	
	Number	%	£M	%
Scotland	33	11	3·8	11
Northern	25	8	3·6	10
North West	46	15	3·3	9
Yorkshire and Humberside	47	15	5·1	15
East Midlands	25	8	2·8	8
West Midlands	44	14	6·6	19
Wales	6	2	0·2	1
East Anglia	4	1	0·5	1
South East	69	22	8·7	25
South West	10	3	0·3	1
Northern Ireland	1	—	—	—
UNITED KINGDOM	310	100	34·9	100

An outline map of the UK is given in Fig. 3(1) showing the Economic Planning Regions which were used as the basis for the regional analysis in the survey.

3.2 Table 3(1) contains the output of the 35 fabricators returning pressure vessel sales of over £200,000, analysed by the regional distribution of the fabricators and the maximum weight of vessel they can build.



**The Northern Ireland Government set up an Economic Council in December, 1964, and has its own scheme of inducements to industry. There is continuing liaison with the United Kingdom Government on regional development policies.*

FIG. 3(1). Outline map of the UK showing the Economic Planning Regions

TABLE 3(1)

Characteristics of fabricators with pressure vessel output over £200,000 in 1966

(Numbers of companies)

UK Economic Planning Region	Maximum size of vessel that can be built (tons)										TOTALS
	1–25	26–50	51–75	76–100	101–125	126–150	151–175	176–200	201–300	300+	
Scotland	—	—	1	—	—	1	—	1	1	—	4
Northern	—	—	—	1	—	—	1	2	—	1	5
North West	—	2	—	1	—	—	—	—	—	1	4
Yorkshire and Humberside	1	1	—	1	1	—	—	—	1	—	5
East Midlands	—	1	1	—	1	—	—	1	—	—	4
West Midlands	—	1	1	1	—	—	—	—	—	1	4
Wales	—	—	—	—	—	—	—	—	—	—	0
East Anglia	—	—	—	—	1	—	—	—	—	—	1
South East	2	3	—	2	1	—	—	—	—	—	8
South West	—	—	—	—	—	—	—	—	—	—	0
Northern Ireland	—	—	—	—	—	—	—	—	—	—	0
TOTALS	3	8	3	6	4	1	1	4	2	3	35

Distribution of fabricators by shop-built pressure vessel output group

3.3 Throughout the present analysis of the UK pressure vessel industry, reference will be made to fabricators according to their 'shop-built pressure vessel output' Group. By this is meant the *range* of shop-built pressure vessel outputs into which the output of any one company fell (during the complete year 1966) as returned on the questionnaires. For brevity these are called PV Output Groups and are defined as follows:

PV Output Group I. £1 to £50,000
II. £50,001 to £200,000
III. £200,001 to £500,000
IV. £500,001 to £1M
V. Over £1M

3.4 A detailed analysis of the questionnaire returns on the basis of PV Output Group is given in Table 3(2). It may be noted that, because of the small number of companies with pressure vessel outputs greater than £½M, Groups IV and V have been amalgamated in this table. The term 'shop-built pressure vessel' excludes, obviously, both 'shop-built heat exchangers and tanks' and 'site-built pressure vessels, heat exchangers and tanks'.

3.5 Some trends are apparent from the PV Output Group characteristics listed in Table 3(2):

the relative importance of pressure vessels increases with their absolute importance; the companies specialising in pressure vessels have generally been building them much longer than the non-specialists;

the pressure vessel production of most companies has increased from 1962 to 1966. Only Group I, the smallest, seems to have failed to have had a general increase;

all Groups seem to assume an increase in production of pressure vessels in the future despite the indications of poor profitability;

satisfaction with profitability of pressure vessels *decreases* as pressure vessel output increases, although output per man *increases* as output increases. This unexpected finding is, however, supported by the observations of J. M. Samuel and D. Smyth (Economics, May 1968) that average profitability on companies' net assets *decreases* as the size of the companies' net assets increase, the results being based on a sample of 186 UK companies over the ten year period 1954–63;

the average number of workers in the heavy fabrication shop increases sharply from Group I to V, suggesting that smallness in pressure vessels is generally associated with smallness in other heavy fabrication activities;

the value of output per man-year increases as the output of pressure vessels increases, suggesting higher productivity in larger companies and that pressure vessels represent the most costly type of heavy fabrication (the increase is too substantial to be explained by higher prices for the same products).

TABLE 3(2)

Characteristics of UK fabricators by 'PV Output Group'

Shop-built PV Output Groups:	I £1–50,000		II £50,001–200,000		III £200,001–500,000		IV & V £500,001+	Shop-built PV output not known		Shop-built PV output nil		TOTAL	
Total number of returns	122		57		24		11	28		24		266	
—from which deduct pilot returns (1)	7		5		5		6	2		2		27	
Base used for percentage in table=	115		52		19		5	26		22		239	
Average % PV output to HFS total output	7%		30%		40%		48%	—		—		—	
	No.	%	No.	%	No.	%	No.	No.	%	No.	%	No.	%
Start of PV production													
Pre–1945	46	40	22	42	10	53	5	13	50	5	23	101	42
1945–1949	12	10	6	12	3	16	—	2	8	3	14	26	11
1950–1954	11	10	9	17	1	5	—	2	8	2	9	25	10
1955–1959	17	15	5	10	2	11	—	1	4	4	18	29	12
1960–1964	24	21	7	13	1	5	—	2	8	2	9	36	15
1965–1967	4	3	—	—	—	—	—	2	8	4	18	10	4
Other answers/blanks	1	1	3	6	2	11	—	4	15	2	9	12	5

Trend of PV production, 1962–6													
Increased	56	49	40	77	12	63	4	9	35	3	14	124	52
Stayed the same	28	24	9	17	4	21	—	7	27	9	41	57	24
Decreased	28	24	1	2	—	—	1	5	19	6	27	41	17
Other answers/blanks	3	3	2	4	3	16	—	5	19	4	18	17	7
Planned future PV output													
Increase	92	80	43	83	8	42	4	17	65	14	64	178	74
Stay the same	16	14	6	12	6	32	—	2	8	5	23	35	15
Decrease	2	2	1	2	1	5	1	1	4	1	5	7	3
Other answers/blanks	5	4	2	4	4	21	—	6	23	2	9	19	8
Profitability of PV production													
Adequate	65	57	18	35	4	21	2	11	42	7	32	107	45
Poor	46	40	29	56	11	58	3	11	42	12	55	112	47
None	2	2	—	—	—	—	—	—	—	1	5	3	1
Other answers/blanks	2	2	5	10	4	21	—	4	15	2	9	17	7
Average number of workers in heavy fabrication shop	63		80		158		349(³)	52(⁴)		110(⁵)		—	
Average output per man, heavy fabrication shop, 1966	£3,784		£4,351		£5,536(²)		£6,855(³)	—		£3,389(⁶)		—	

(¹) The questions answered in this Table were not asked in the Pilot Questionnaire.
(³) Based on 9 returns; the information is not given on the other 2.
(⁵) Based on 21 returns.

(²) Based on 18 returns.
(⁴) Based on 21 returns.
(⁶) Based on 19 returns.

Distribution of fabricators by size of pressure vessel output

3.6 Fig. 3(2) shows fabricators' returns of output and capacity analysed by the shop-built pressure vessel output groups defined above. The main points are summarised below.

3.7 PV Output Groups I and II together and PV Output Group V, each accounted for some 30% of output, and companies with an output of between £200,000 and £1,000,000 for the remaining 40%. In more detail:

Output of shop-built pressure vessels, 1966

Output group	£M	%
I. £1–50,000	2·2	8
II. £50,–200,000	6·2	21
III. £200,–500,000	7·7	25
IV. £500,–1,000,000	3·7	13
V. £1,000,000+	9·4	32
TOTAL	29·1	100

3.8 Twenty-four fabricators (9% of the pressure vessel fabricators returning the questionnaire) had no vessel output in 1966. Some noted on their returns that they could get no orders. Only one planned a decrease in future vessel output (Table 3(2)).

3.9 Output of pressure vessels and heat exchangers accounted for a high proportion of heavy fabrication shop output in 1966 for the two largest output groups (over £500,000) and none of these companies had spare capacity in that year. The output of the 11 largest companies making returns may therefore be taken as close to their capacity in 1966. The figures are outlined below (see page 40):

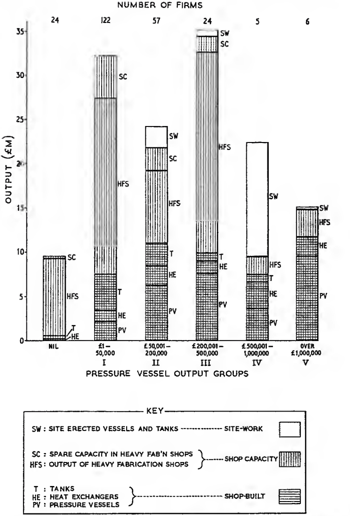


FIG. 3(2). Output and capacity of the UK pressure vessel industry in 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups)

Returned output in 1966

	Companies with shop-built pressure vessel output of			
	£200,001–500,000	£500,000+	£200,000+	
	£M	£M	£M	% of returns from all PV Output Groups
Shopbuilt				
Pressure vessels	7·7	13·1	20·8	71
Heat exchangers	1·3	5·1	6·4	66
Tanks	1·0	1·0	2·0	22
Total	10·0	19·2	29·2	61
Other heavy fabrication	22·5	5·3	27·8	43
Total HFS	32·5	24·5	57·0	50
Spare capacity	1·9	—	1·9	21
TOTAL SHOP CAPACITY	34·4	24·5	58·9	48
Sitework	0·7	12·8	13·5	84

The importance of pressure vessels in heavy fabrication shop output

3.10 Figs. 3(3) and 3(4) show the distribution of companies and of shop pressure vessel output according to the relative importance of pressure vessels in heavy fabrication shop output. The picture that emerges is as follows:

Pressure vessels as % heavy fabrication shop output	*No. of companies*		*Pressure vessel output*	
	No.	%	£M	%
Up to 10%	74	36	2·1	7
11–20	35	17	3·1	11
21–30	15	7	1·1	4
31–40	21	10	3·5	12
41–50	12	6	1·9	7
51–60	10	5	1·4	5
61–70	10	5	4·0	14
71–80	12	6	2·7	10
81–90	9	4	4·4	16
91–100	7	3	3·9	14
TOTAL	205	100%	£28·1M	100%

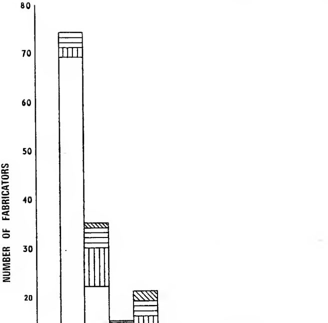


FIG. 3(3). *UK numbers of fabricators returning questionnaires* (analysed by shop-built pressure vessel output groups and percentage of pressure vessel output to total output of the heavy fabrication shop)

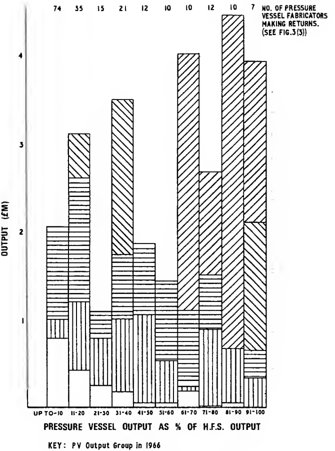


FIG. 3(4). *UK output of shop-built pressure vessels in* 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups and percentage of pressure vessel output to total output of the heavy fabrication shop)

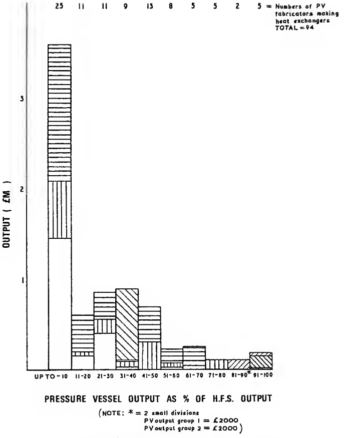


FIG. 3(5). *Output of heat exchangers in* 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups and percentage of pressure vessel output to total output of the heavy fabrication shop)

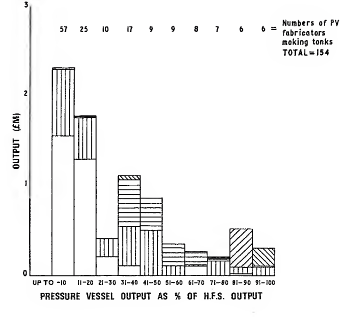


FIG. 3(6). *Output of shop-built tanks in* 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups and percentage of pressure vessel output to total output of the heavy fabrication shop)

3.11 The 49 companies (24% of those giving the relevant information) for whom pressure vessels accounted for 50% or more of their heavy fabrication shop output produced £16·4M of shop vessels in 1966, 59% of the total returned on the questionnaires. These companies whose prosperity depended heavily on pressure vessels, were divided by output group as follows:

Pressure vessel output group	*No. of companies*		*Pressure vessel output*	
	No.	% of total in group	£M	% of total in group
I. £1–50,000	10	20	0·3	2
II. £50,–200,000	22	46	2·3	14
III. £200,–500,000	9	18	2·7	16
IV. £500,–1,000,000	2	4	1·4	9
V. £1,000,000+	6	12	9·7	59
TOTAL	49	100	£16·4M	100%

3.12 Figs. 3(5) and 3(6) show fabricators' returns of output of heat exchangers and shop-built tanks in 1966 analysed in the same way as for Fig. 3(4), so that the corresponding columns in these three output charts all relate to the same companies. It can be seen that most tank and heat exchanger output by pressure vessel fabricators is accounted for by those for whom pressure vessels represent a minor part of shop output. The relationship between tank and heat exchanger output and absolute size of pressure vessel output is summarised below:

Pressure vessel output group	*Heat exchanger output*			*Tank output*		
	No. of companies	£M	%	No. of companies	£M	%
I. £1–50,000	45	2·2	29	91	3·3	40
II. £50,–200,000	29	1·3	17	43	2·8	34
III. £200,–500,000	15	3·0	40	14	1·4	17
IV. £500,–1,000,000	4	0·9	12	4	0·3	4
V. £1,000,000+	1	0·1	1	2	0·4	5
TOTAL	94	7·5	100	154	8·2	100

The table shows that companies whose pressure vessel output was below £200,000 accounted for three-quarters of tank output by vessel fabricators, but less than half of heat exchanger output.

3.13 A final subjective indication of the importance of pressure vessels to companies is given by the analysis in Figs. 3(7) and 3(8) of their answers to the question whether vessels were a principal, secondary or occasional activity of the heavy fabrication shop. Fig. 3(7) shows that the numbers of answers were divided fairly evenly between 'principal' on the one hand and 'secondary' or 'occasional' on the other, but Fig. 3(8) shows that some 80% of output in 1966 was accounted for by those claiming pressure vessel fabrication as a principal activity. It should also be noted that some of the largest producers classed pressure vessel fabrication as only a secondary activity.

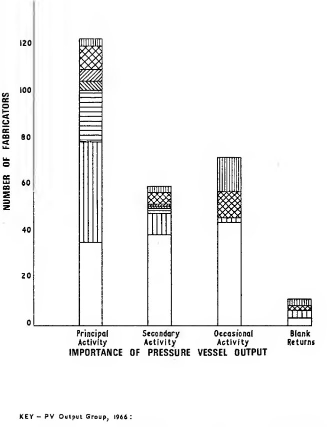


FIG. 3(7). *Numbers of fabricators returning questionnaires* (analysed by shop-built pressure vessel output groups) and *importance of shop pressure vessel output to the company*

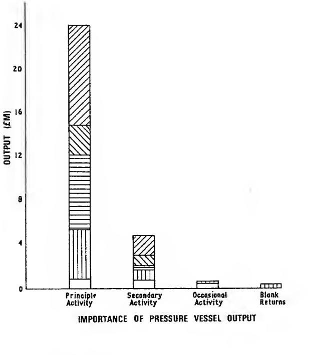


FIG. 3(8). *Output of shop-built pressure vessels in* 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups and *importance of shop pressure vessel output to the company*)

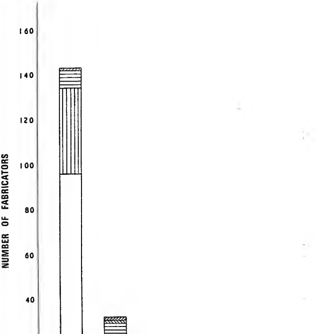


FIG. 3(9). *Numbers of fabricators* returning questionnaires, analysed by shop-built pressure vessel output groups *and maximum crane lifting power*

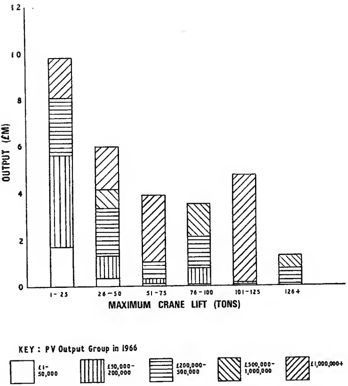


FIG. 3(10). *Output of shop-built pressure vessels in* 1966, (as returned on questionnaires, analysed by shop-built pressure vessel output groups *and maximum crane lifting power*)

Cranage and the maximum weight of vessel that can be built

3.14 Figs. 3(9) and 3(10) bring out the rather surprising fact that some of the largest producers of vessels in 1966 have very low cranage in their shops. Some companies can, of course, manufacture vessels much larger than their cranage would suggest. Details of maximum cranage are given below for the largest producers:

Maximum crane lift in tons	*No. of companies with 1966 Shop-Built Pressure Vessel Output of*		
	£200,000– £500,000	£500,000– £1,000,000	£1,000,000+
Up to 25	8	—	1
26–50	7	1	1
51–75	3	—	1
76–100	4	2	—
101–125	—	—	3
126+	2	1	—
TOTAL	24	4	6

3.15 For the same companies (with shop-built PV output greater than £0·2M) the following table analyses the maximum weight of vessel companies said they could build (this information was asked only in the revised long questionnaire and was obtained by letter or telephone call from relevant companies returning other questionnaires). Certain differences are apparent: while 6 companies claimed to be able to move vessels of over 100 tons by crane, 15 companies claimed to be able to build vessels of this weight. The details are given below, analysed by the materials handled by the companies and an analysis of this information by region has already been given in Table 3(1). It may be noted in addition that altogether 11 companies (i.e. including companies with shop-built PV output *less* than £0·2M) reported cranage capacity of over 100 tons.

Maximum weight of vessel that can be built (tons)	No. of companies with shop-built pressure vessel output of								
	£200,000– £500,000			£500,000– £1,000,000			£1,000,000+		
	Mild steel	Stainless	Both	Mild steel	Stainless	Both	Mild steel	Stainless	Both
Up to 25	—	1	2	—	—	—	—	—	1
26–50	—	2	4	—	—	—	—	—	1
51–75	1	—	2	—	—	—	—	—	—
76–100	—	—	4	—	—	2	—	—	—
101–125	—	—	1	—	—	1	—	—	2
126–150	—	—	—	—	—	1	—	—	—
151–175	—	—	—	—	—	—	—	—	—
176–200	—	—	2	—	—	2	—	—	1
201–300	—	—	2	—	—	—	—	—	—
300+	—	—	2	—	—	—	—	—	1

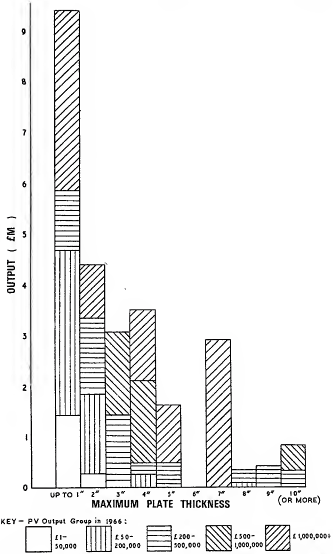


FIG. 3(11). *Output of shop-built pressure vessels in* 1966 (as returned on questionnaires, analysed by shop-built pressure vessel output groups *and maximum thickness of mild steel* the company can edge prepare, roll or bend, and weld without normally subcontracting)

Maximum mild steel plate thicknesses

3.16 Fig. 3(11) analyses shop pressure vessel output in 1966 by the maximum mild steel plate thickness companies can handle without sub-contracting some of the production processes. The chart is based on the number of companies answering the relevant question. From other questions it was apparent that many companies claimed to handle both mild and stainless steel and that some claimed ability to weld plates much thicker than they could roll or edge prepare.

3.17 The chart also shows that, as some of the largest producers in the industry in 1966 have very low cranage, so also they can handle only relatively thin plate. The summary table below includes separate analyses for the larger fabricators in 1966, for mild steel pressure vessels without sub-contracting.

Maximum plate thicknesses for mild steel vessels without sub-contracting:

Maximum plate thickness	All PV Output Groups				PV Output Groups III to V (i.e. PV output greater than £200,000)			
	No. of companies	%	Output £M	%	No. of companies	%	Output £M	%
Up to 1"	126	66	9·4	34	6	21	4·7	23
2"	34	18	5·4	19	6	21	3·6	18
3"	12	6	3·1	11	6	21	2·9	14
4"	8	4	3·5	13	4	14	3·2	16
5"	3	2	1·6	6	2	7	1·6	8
6"	—	—	—	—	—	—	—	—
7"	1	1	2·9	11	1	3	2·9	14
8"	2	1	0·3	1	1	3	0·3	1
9"	1	1	0·4	1	1	3	0·4	2
10" or more	3	2	0·8	3	2	7	0·8	4
TOTAL	190	100	27·5	100	29	100	20·4	100

Companies fabricating only in stainless steel

3.18 Only 8 of the fabricators returning questionnaires specialise in stainless steel. Their total pressure vessel output in 1966 amounted to £1,280,000. More information about these companies is given below:

Maximum crane lift in tons	*Stainless steel vessel fabricators pressure vessel output group* II. £50,001–£200,000 No.	III. £200,001–£500,000 No.
0–5	1	—
6–10	2	1
11–20	1	1
21–30	1	1
TOTAL	5	3

(Pressure vessel output in 1966 by PV Output Group:
Group II=£500,000; Group III=£780,000)

Companies with large site-built output

3.19 In contrast to the many fabricators with modest *shop-built* pressure vessel outputs, the site-built activities of companies returning the long questionnaire was concentrated being shared between 6 major companies (two companies in each of the shop-built PV Output Groups II, III and IV). These six companies were responsible for 98% of the output of site-built pressure vessels and tanks (spheres) in 1966 by the companies returning the long questionnaire. Of these, the three leading companies were responsible for 80% of the site-built output.

Example of variation of orders received by fabricators: 1962–1967

3.20 Eighteen companies were able to provide a historical series of orders received during the period 1962–67. It is based on a small number of fabricators (responsible for about one-third of the pressure vessel production) and the result is not statistically significant. However, the series is of interest as it illustrates the sharp fluctuations known to occur in the pressure vessel market and it is therefore shown in Fig. 3(12).

Trade associations and other groupings

3.21 The membership of TIPA, the most important grouping of pressure vessel fabricators, especially in carbon steels, is 84 different companies. All the members are capable of producing good quality, though not necessarily Class I fabricated, pressure vessels, tanks or heat exchangers, although for nearly half the membership such activity may be secondary to another type of fabrication.

3.22 Some 41 members of the BCPMA appear to be pressure vessel manufacturers of significance, and 26 members of BCPMA are also members of TIPA.

3.23 Some 50 companies in the UK are on the Lloyds' Class I list for pressure vessels; of these 29 are members of TIPA.

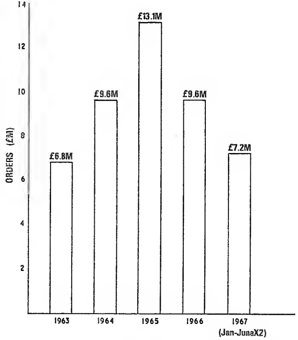


FIG. 3(12). Orders for shop-built pressure vessels received by 18 companies in the UK, (1963 to first half 1967)

CHAPTER 4

UK supply: commercial and technical factors

4.1 In the course of the economic survey interviews were held with some thirty-five fabricators to obtain a greater understanding of problems facing the pressure vessel industry and the causes of and possible solutions to these problems. These interviews were designed to augment the quantitative data acquired from the questionnaires and to provide evidence upon which conclusions could be drawn with regard to the structure of the industry, management attitudes, production equipment, labour availability and labour relations, market orientation, marketing methods and the numerous other factors which go to determine the competitiveness of a particular sector. These interviews constitute the qualitative 'supply' evidence for the UK part of the survey, and a full account is given in Annex C.

4.2 A brief note on pressure vessel design standards and on inspection procedures is also given towards the end of the present chapter, and a full account is given in Annex D.

4.3 Certain suggestions for change are made in this brief chapter which, if followed, would, it is believed, have considerable repercussions on the industry and align it more with practice in most continental European countries.

Personnel

4.4 The *management* of much of the industry tends to be conservative and has not generally shown the qualities necessary for the efficient operation of current activities of companies or an awareness of the factors upon which decisions for the future should be based. A reason for this lies in the structure of the British heavy engineering industry. It is a long-standing industry resistant to change with many in-built attitudes in both management and labour. Because of this conservatism, there has been a reluctance to search for radical alternative methods and policies which are increasingly needed. It is difficult to attract young engineering management potential due to the salary scales offered and the relatively limited career opportunities which the small fabricating companies can offer.

4.5 There is a shortage, except during the periods of abnormally low demand, of *skilled labour* in the industry due to a number of factors:

the market fluctuations for pressure vessels have necessitated the lay-off of skilled labour, which is then taken by other industries offering, at times, higher wages and frequently less arduous working conditions;

it is hard to recapture this labour when pressure vessel demand picks up;

the present demarcation practice at the shop floor level of the relevant engineering unions inhibits the most efficient use of available skilled labour;

the insistence by the relevant unions that skilled labour elements can only be made up by men who have gone through the normal apprenticeship schemes.

4.6 The specialisation of trades means that the plater generally cannot do the welder's job and vice-versa. Pressure vessels are all dissimilar and since the work load fluctuates, the concentration of work in the heavy shop varies between plate forming and final assembly. Thus the amount of work available at any one time for each trade must vary. According to the rules of demarcation it is quite possible for one group of skilled men to be idle while the others cannot cope with the work load and are thus causing an artificial bottleneck.

4.7 As most fabricators have union shops, the problems raised by demarcation are considerable. If this could be eliminated, it would contribute more than any other single factor towards increasing further the competitiveness of the UK pressure vessel industry.

Sales and marketing

4.8 The main *customer* for the pressure vessel fabricator is the chemical engineering contractor, although 30%–40% of pressure vessel sales in the United Kingdom are estimated to go direct to final users. The buyers of pressure vessels normally issue requests for tenders to a large number of fabricators, specifying the vessel often to the point of a complete drawing. While some clients prepare complete drawings, others leave the details of the design to the fabricator, who may receive no more than a sketch. The buyer will normally use previous experience of fabricators as a guide in sending out requests for tenders. Price and delivery are almost invariably the criteria for the allocation of the order.

4.9 The disbalance of supply and demand, which has characterised the market in pressure vessels during the past five years, has resulted in less competitive prices and long deliveries from the British industry in periods of high demand, together with imports from, principally, Italy. In the periods of low home demand, sharp competition between the British fabricators has resulted in price cutting and a low or non-existent profitability. The sharp market fluctuations have been unsatisfactory for both the pressure vessel industry and its customers.

4.10 The success rates—ratio of orders received to tenders sent—of fabricators are very low and about 5% is not uncommon; more could be done by the chemical contractors and final users to use negotiated ordering and very limited tender. Negotiated ordering would be particularly helpful for big specialist fabricators by enabling them to plan their fabrication and development. The pressure vessel procurers could also ensure that the engineering talent of a fabricator for a particular vessel was not overlooked by entirely commercial buying criteria. However, normal commercial factors will largely dictate buying policies.

4.11 The *selling methods* of British pressure vessel fabricators consist largely of reminding the limited number of contractors and main final users generally of the existence of their company and specifically in the context of a particular potential order. Travelling salesmen are used, but the main emphasis is put on management or director level contacts with the customer. The salesmen of many British fabricators are rarely more than technicians in training, and compare unfavourably with the British engineering sales agents of the leading foreign fabricators in their knowledge of design and the capacity and characteristics of their company's fabrication shop.

4.12 *Market research* is virtually non-existent and the absence of knowledge of the process applications of pressure vessels means that fabricators do not have enough advance warning of changes in their market.

4.13 With very few exceptions, British fabricators have not tried to achieve *direct exports* (i.e. other than through a British-based contractor) as an essential cushion to fluctuations in the domestic market.

Design

4.14 The design of pressure vessels can be divided between the 'chemical'—operating conditions, overall dimensions, position of openings—and the 'mechanical'—the structural design and production drawings. The former should be the province of the customer (end-user or contractor) and the latter in the hands of the pressure vessel fabricator.

4.15 Modifications to design by customers when fabrication has started constitute a serious loss of fabrication time. The fabricator is rarely able to recuperate the full losses from the customer. A system is suggested which would progressively (in time) fix more details of the design of a pressure vessel to coincide with the stages of pressure vessel fabrication. Any modification after each guarantee date should result in the fabricator being able to recuperate all or part of the additional costs involved.

Estimating

4.16 There is not enough screening of requests to tender and this could be changed through the definition by fabricators of their shop specialisation. The basic estimating method is to list and cost materials, estimate the man-hours, by trade, involved in the vessel construction and add to the labour costs so calculated a block overhead of 200% or more. Target profit (normally 10–15%) is then added to the total.

4.17 Considerable variations occur in the methods of defining and calculating direct labour; accuracy in the allocation of overheads varies according to the sophistication of the company. The accuracy in the labour input frequently leaves a lot to be desired, due mainly to a lack of real production figures and historical costs, and to an opposition from organised labour in many companies towards the introduction of work study.

Procurement

4.18 Most *steel plate* for pressure vessels is bought from the mills due to the variety of specifications and dimensions required. Delivery from the steel industry proved, particularly in 1966, to be a cause for delay in pressure vessel production, particularly for alloy and clad steel.

4.19 A number of complaints were made by fabricators with regard to defects in steels such as laminations, inclusions or pittings. These frequently necessitated replacement and remaking by the steel mill. The losses involved in finding an internal fault at an advanced stage of fabrication were so high that many fabricators undertook their own ultrasonic testing on plates. Many Continental steel mills, however, carried out ultrasonic testing free at their works whereas British mills made an extra charge of 20%.

4.20 *Forged components* had been another reason for delays in the delivery of pressure vessels, and certain apparent areas for improvements in the pressure vessel industry appeared to apply to the forging industry.

4.21 The supply of *dished ends* had been, at times, a significant cause of pressure vessel delivery delays, and was largely in the hands of a dozen specialist fabricators.

Production

4.22 The *equipment* in the British pressure vessel industry is generally comparable with that installed in the fabrication shops of other countries, although there are examples of better equipment in some foreign fabricators. The heavy fabrication industry in the United Kingdom has not been particularly profitable for a number of years and there has been an apparent shortage of capital for modernisation, although companies convinced of the need to modernise have always found the necessary finance. Some new equipment is under-utilised due to the often uneconomical size of production units and lack of effective study before the purchase of equipment.

4.23 *British shop layout*, due to the age of many shops, is not usually laid out to suit the sequence of pressure vessel manufacture or the movement of heavy work pieces. On a given site, even for large companies, there is a preponderance of small shops rather than one or two large multi-bay shops.

4.24 The *planning and control* of production, with some notable exceptions, is inefficiently organised in many companies. Planning systems showing the pre-production path and progress of the vessel according to the adopted plan are often inadequate and there is a low proportion of actual working time during the production of a vessel. The implementation of an efficient planning system has been made more difficult by a lack of flexibility in the use of the labour force due to demarcation; by flaws in steel plate necessitating rejection and replacement; by changes in design by the customer; and by delays inherent in the current inspection systems.

Trade associations

4.25 The main trade association representing the pressure vessel fabricator is the Tank and Industrial Plant Association (TIPA). This association acts as a forum for many pressure vessel fabricators. Some companies, on the other hand, belong to the British Chemical Plant Manufacturers' Association (BCPMA) which covers pressure vessels as well as chemical plant in general.

4.26 It would be useful if TIPA could widen its membership to cover all pressure vessel fabricators, particularly those working in stainless steel and non-ferrous metals, so that it could become fully representative. TIPA could play a valuable role in publicising the industry by publishing a booklet entitled, for example, "the British Pressure Vessel, Tank and Heat Exchanger Manual", which would oblige the individual fabricators to define their production specialisation. TIPA could also provide a useful centralised market research service for the industry, particularly for the smaller companies who could not afford individually to support the costs of such a service.

Research and development

4.27 There is little fundamental and objective research among even the large fabricators. Development work is mainly concerned with new welding techniques and the welding of new materials. Most of the welding work is directly or indirectly connected with the British Welding Research Association and often consists of developing a new BWRA process to the production stage. Companies belonging to groups benefit from the advantages of centralised research services.

4.28 The expenditure on research and development carried out by the British pressure vessel fabricators was, in the opinion of the Battelle Institute, probably equal to or greater than its foreign competitors. A greater degree of communication should exist in the industry to permit the fullest advantage to be taken of significant findings.

Pressure vessel design standards and inspection procedures

4.29 Design standards are concerned with both safety and good design practice. Inspection is concerned with current practice and can provide a valuable feed-back for modification of design standards.

4.30 There is no explicit statutory obligation to use specified design standards or codes (BS or foreign) in the UK. Some degree of enforcement seems necessary, but legal backing acting directly on a design standard may be stifling to design standard modification. The bodies carrying out inspection virtually administer the design and inspection standards through their day-to-day interpretations and through the effect of their membership on the committees of BSI. There is, however, little feed-back of ideas into the design standards by this means, nor has BSI any statutory or other responsibility for the inspection organisations' activities.

4.31 Two quite different British standards are available in the UK; BS 1500 and BS 1515. The former, like ASME Section VIII which it resembles in other ways, bases its design stress on the UTS. Modern engineering thought accepts that the UTS is a poor basis for design stress and that yield stress is more relevant. In practice, standards using UTS/4 for the room temperature design stress demand much higher thicknesses than standards using YS/1·5.

4.32 BS 1515 is more advanced though less complete than BS 1500, but still takes the UTS into consideration. Accordingly, a standard including yield stress only, such as the German TUV, has a definite advantage in wall thickness when using advanced steels. It is only when the design stress is based on yield stress that advanced steels become economically interesting, and British competitiveness suffers as a direct result of the use of UTS orientated design standards.

CHAPTER 5

UK demand: qualitative review

5.1 The following brief chapter summarises qualitatively the significant pressure vessel demand sectors and the likely changes in demand in each of the user sectors studied. A full account is given in Annex E, and a tabular summary of the position in 22 industrial sectors is given in Table 5(1).

Mineral oil refining

5.2 The more advanced vessels are:

distillation columns
  pressures : 200–250 psig
  dimensions : 7–14′ diameter, up to 200′ high
  temperature : up to 200°C
platformers
  pressures : 400–500 psig
  dimensions : 15′ diameter, 30–45′ high
  temperature : up to 550°C
hydrocrackers : this is a relatively new element in refineries
  pressures : 1,500 psig increasing to 2,000 psig
  dimensions : 18′ diameter, 60′ long, wall thickness up to 8″
  temperature : about 400°C

5.3 Special alloys are needed and whilst the UK has been able to deal with many vessels it has not always been possible to supply the materials and/or fabrication required for these special alloys. On the other hand some leading Japanese and German fabricators were advanced in the techniques of dealing with such alloys.

5.4 In the longer term future, operating pressures, temperatures and unit sizes will tend to rise. Standardisation except for LPG storage tanks is not considered feasible.

Town gas

5.5 Future requirements for pressure vessels will mainly be for storage purposes. Typical examples are:

high pressure gas holders
  pressure : 350 psig
  dimensions : 12′ diameter, 192′ long
  material : mild steel with grade 32A the most popular
butane bullets (for LPG)
  either : 100 ton capacity, 12′ diameter, 70–80′ long
  or : 150 ton capacity, 15′ diameter, 90′ long
  pressure : maximum operating is 210 psig

TABLE 5(1)

Overall UK demand for pressure vessels: analysis of vessels and likely technical trends in use

	INDUSTRIAL SECTORS / TYPES OF VESSEL	PRIMARY								SECONDARY									OTHER				
		Mineral oil refining	Town gas	Electricity generation	Heavy organic chemicals	Fertilizers and pesticides	Inorganic chemicals	Dyestuffs	Industrial gases	Fine chem, pharmaceuticals, toilet prep.	Coke ovens and coal tar products	Synthetic resins and plastics	Vegetable and animal oils and fats	Sugar refining	Food and drink NES	Pulp and paper	Cement	Transport	Brewing	Synthetic rubber	Polishes	Gelatine and adhesives	Soap and detergents
TANKS	Tanks, plate small, erected on site	ps	pd		ps	os	os				os		os	os	os					os		os	os
	Tanks, shop built		od			os	os	os		os	os	os	os	os	ps	ps	ps	pg	ps	os	ps	pg	ps
PRESSURE VESSELS AND HEAT EXCHANGERS	Carbon and low alloy steel	pls phg	old phd	pld phs	pls phg	pls	pls ohs	pld ohd		pld	pls ohs	pls	pls	pls	pls			plg	pld	pls ohg	pls	pld	olg
	High alloy steel inc. high tensile	ohg	phd	plg		olg	olg																
	Stainless and nickel alloys inc. clad	olg ohg	old ohd	ols	pls phg	plg ohg	olg oh	plg ohg	plg phg	pls	olg	ols	olg	plg	plg			olg	olg	ols ohg	pls		olg
	Aluminium and its alloys						ols		pls									olg					
	Glass, reactive metal and solid resin clad	olg						plg		ols		ols							pld	pls ohg			
	Spheres	ohg	ohg						olg														
	Pressure vessel trends	hg	hd	ls	hg	hg lg	ls	ls hs	hg	ls	ls	ls	ls	ls	ls	ls	ls	ls	lg	ls	ls	ls	ls

Source: Interview programme

Symbols:
p = principal
o = occasional and secondary
l = low pressure (less than 300 psig)
h = high pressure (more than 300 psig)
g = use growing in plant
s = use static in plant
d = use declining in plant

5.6 The replacement of ASME Code by BS1515 has reduced costs considerably.

Heavy organic chemicals

5.7 This sector is a most important outlet for pressure vessels of all types and, as with the refinery industry, also for very large, thick walled special material vessels. Stainless steel vessels are particularly important in the oxidation reactions, and in the context of corrosion resistance an increasing usage of titanium-lined vessels can be expected. While sophisticated materials are required, shell thicknesses rarely exceed 2″ as pressures remain lower than in some refinery processes. Future trends will accentuate these requirements.

Fertilizers

5.8 Pressures are relatively low (less than 100 psig) with the exception of urea which in one process requires pressures of 3,000 psig and temperatures of 200°C. One basic chemical for fertilizers (ammonia) also requires, in certain processes, high pressures (up to 5,000 psig). In final fertilizer manufacture stainless steel is commonly used to meet corrosive conditions.

5.9 For the future, unit sizes of plants are increasing and pressures will become higher. There will be a greater use of stainless steel and of some titanium; for high pressure ammonia plants high strength quenched and tempered steels can be expected to find an application.

Inorganics

5.10 Technical change is less rapid here than in the refinery or heavy organics fields. The period to plant obsolescence is longer. Continuous production techniques are used for all 'tonnage' chemicals. Most vessels are in mild steel with some use of special linings. Pressures are normally below 350 psig. Some standardisation of vessels for simpler applications is being attempted.

Other sectors

5.11 Industrial gases and electricity generation are also of interest for certain special vessels. The transport section, road and rail tankers, offers the possibility of series production, and, therefore, specialisation. It is not a field of interest to the jobbing fabricator.

CHAPTER 6

UK demand: present data and future estimates

Introduction

6.1 To determine historic demand data and future demand estimates for pressure vessels, it has been necessary to divide UK demand into a number of major demand sectors and consider each in detail. Demand in the UK has therefore been considered in the following sections in the present chapter:

(a) the special role of contractors in the UK;

(b) the trends in fuel policy in the UK, and the effect this will have on future demand in the gas, electricity and oil sectors of the economy;

(c) gas: past data and future estimates of demand;

(d) electricity: past data and future estimates of demand;

(e) oil: past data and future estimates of demand;

(f) chemical industry: past data;

(g) chemical industry: various future demand estimates, based on considerations of general economic growth;

(h) UK demand pattern for vessels in four major sectors: past and future estimates.

It is important to note that all the determinations of historic demand data and, more particularly, of estimates of future demand levels are subject to considerable margins of error. All estimates in the present chapter should therefore be treated as providing only a very approximate guide to demand levels.

6.2 The economic growth of the UK provides a standard of growth against which the past and future estimates of demand in the individual industrial sectors (listed above) may be compared. Fig. 6(1) shows the growth of the UK gross domestic product during the period 1950–66 at 1958 prices: the overall growth is approximately 3% per annum.

6.3 It may be noted that the past and future estimates of demand considered herein relate to both shop and site-built pressure vessels, heat exchangers and tanks. For the sake of brevity, when *all* these categories are intended, the word 'vessels' will be used in the present chapter.

The role of contractors in the UK

6.4 From the standpoint of the pressure vessel industry, both contractors and final users are procurers of vessels; it is estimated that about 60%–70% of the vessels procured in the four main demand sectors in the UK are bought by contractors (including the contracting divisions of major plant users) for installation in complete plants. Although the contractor is not a generator of vessel demand, he is an important link in the demand circuit, and the criteria which he uses for the purchase of vessels are a determining factor in the market conditions for vessels. There are about twenty

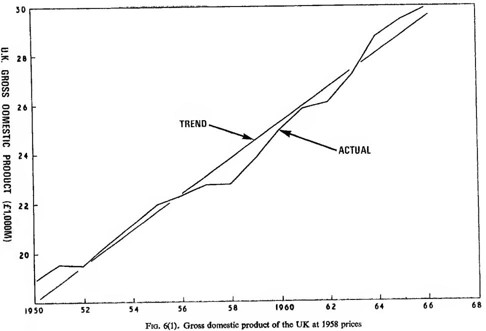


FIG. 6(1). Gross domestic product of the UK at 1958 prices contractors or contracting divisions of standing in the UK that can be classified as follows:

(a) six British companies that are members of the British Chemical Engineering Contractors' Association (BCECA);

(b) about eight American companies, invariably major subsidiaries of the large American contracting groups;

(c) approximately six other British companies that operate as contractors but frequently carry out this operation as part of other group activities which may or may not be contracting.

6.5 As a generalisation, group (a) has tended in the last few years to take a significant volume of its work from the gas industry together with heavy organics, inorganics and fertilizers. Group (b) has been dominant in the refinery field and certain areas of heavy chemicals. Group (c) has mainly consisted of specialists such as:

the contracting arm of a major synthetic fibre producer;

a specialist contractor in synthetic fibres;

a large civil engineering contractor using design and construction expertise but not offering proprietary processes.

6.6 The chemical contractor in the UK in post-war years has to a large extent replaced part of the role of the engineering department of the final user. It may be estimated that the share of chemical plant procurement through the chemical contractor will increase.

6.7 The major vessel demand sectors have been:

mineral oil refining;

the town gas industry;

the main sectors of the chemical industry such as heavy organics, fertilizers, inorganics and dyestuffs.

Contractor activity has been very significant in all these areas. However, in the less important demand sectors the small scale of plants and the simpler process operations frequently imply procurement by the final user direct from the pressure vessel manufacturer, with plant erection and civil engineering entrusted to a general engineering contractor.

6.8 Pressure vessels not passing through the hands of contractors are more likely to be for replacement and modification, and for small plants (not turnkey). However, a number of large final users may, for new plants, use contractors for engineering and site erection while retaining control of procurement. For small plants, where contractors are not active, a high stainless steel content is found and stainless specialists have a smaller proportion of their customers as contractors. This market structure, with the strong intermediary role of the contractors has, as a direct consequence, the effect of cutting off the mechanical engineer in the fabricator from the chemical engineer in the final user.

6.9 The only significant variation in the market pattern is in the supply of power generation plant to the Central Electricity Generating Board, where vessels may be fabricated as part of complete plant by the same company or group that is responsible for design and installation. Even here, however, the main contractor for a power station may buy in much of the plant (such as the boiler drums).

TABLE 6(1)

Gross fixed capital formation in the UK at current prices (£M)

YEAR	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Mineral oil refining																		
Plant and machinery	21	29	30	25	13	11	17	33	32	20	11	19	15	23	25	24	43	88
Other new buildings and works	11	5	10	8	3	2	5	9	7	3	4	5	2	3	3	5	7	5
Vehicles	—	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	1
TOTALS	32	34	40	33	16	13	22	42	40	23	15	24	17	27	28	29	50	94
Chemical industries																		
Plant and machinery	41	53	55	63	70	73	95	110	114	109	96	124	124	100	134	181	219	174
Other new buildings and works	14	20	24	27	24	27	34	35	37	30	31	36	40	29	31	36	32	31
Vehicles	2	3	3	3	3	4	5	5	6	6	7	7	6	7	9	11	11	10
TOTALS	57	76	82	93	97	104	134	150	157	145	134	167	170	136	174	228	262	215
Electricity																		
Plant and machinery	100	111	122	138	162	196	199	209	229	272	275	299	333	428	496	524	593	571
Other new buildings and works	36	36	36	41	51	50	48	56	67	67	61	63	77	80	109	127	121	124
Vehicles	2	2	1	1	2	2	2	1	1	2	2	2	2	2	2	3	4	3
TOTALS	138	149	159	180	215	248	249	266	297	341	338	364	412	510	607	654	718	698
Gas																		
Plant and machinery	23	27	31	30	31	34	29	28	28	24	23	20	28	46	40	53	102	149
Other new buildings and works	9	12	14	16	20	24	21	23	21	21	20	21	28	35	47	49	83	133
Vehicles	1	1	1	1	2	1	1	2	2	1	1	1	1	1	—	1	1	2
TOTALS	33	40	46	47	53	59	51	53	51	46	44	42	57	82	87	103	186	284

Source: National Income and Expenditure Blue Book

TABLE 6(2)

Gross fixed capital formation in the UK at constant (1958) prices (£M)

YEAR	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
Mineral oil refining																		
Plant and machinery	30	39	37	30	15	12	18	34	32	20	11	18	14	21	23	21	36	—
Other new buildings and works	16	7	12	10	4	2	5	9	7	3	4	5	2	3	3	4	6	—
Vehicles	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
TOTALS	46	46	49	40	19	14	23	43	40	23	15	23	16	25	26	25	42	75
Chemical industry																		
Plant and machinery	59	72	67	75	82	82	101	113	114	109	95	118	116	93	122	156	181	—
Other new buildings and works	21	26	29	32	29	30	37	36	37	30	31	36	38	27	28	31	27	—
Vehicles	3	3	3	3	3	4	5	5	6	6	7	7	6	8	10	12	12	—
TOTALS	83	101	99	110	114	116	143	154	157	145	133	161	160	128	160	199	220	174
Electricity																		
Plant and machinery	145	150	149	164	191	220	212	215	229	272	272	285	311	396	451	452	490	—
Other new buildings and works	53	47	43	49	61	56	52	58	67	68	62	63	74	73	97	110	102	—
Vehicles	3	2	1	1	2	2	2	1	1	2	2	2	2	2	2	3	4	—
TOTALS	201	199	193	214	254	278	266	274	297	342	336	350	387	471	550	565	596	591
Gas																		
Plant and machinery	33	36	38	36	36	38	31	29	28	24	23	19	26	43	36	46	84	—
Other new buildings and works	13	16	17	19	24	27	23	24	21	21	20	21	27	32	42	43	70	—
Vehicles	1	1	1	1	2	1	1	2	2	1	1	1	1	1	—	1	1	—
TOTALS	47	53	56	56	54	66	54	55	51	46	44	41	54	76	78	90	155	232

Source: National Income and Expenditure Blue Book

Trends in fuel policy in the UK

6.10 Past trends and future prospects in the gas, electricity and oil industries are largely the products of: technological progress; the Government's fuel policy in the light of this technological progress; and the financial and political factors that must also be taken into account. Outstanding developments are summarised in this introductory section on fuel policy as they effect all three pressure vessel demand sectors. Reference is made throughout this chapter to the National Income and Expenditure figures of capital formation in the UK; these are given for the period 1950–67 for the sectors of gas, electricity and oil as well as for the chemical industries (considered in a later section of this Chapter) in Tables 6(1) and 6(2).

6.11 The decade 1956–66 was characterised by the rapid growth of oil consumption at the expense of coal and by the emergence of nuclear power as a competitive primary energy source. The next decade will be marked by rapid exploitation of the natural gas reserves in the North Sea and the continued growth of nuclear power. The relative growths of the oil, nuclear and gas sectors are shown in Table 6(3).

TABLE 6(3)

Relative fuel consumption in the UK based on million tons coal equivalent data

Sector	1957	1966	1975
	Actual (%)	Actual (%)	Estimated (%)
Coal	85	59	34
Oil	14	38	42
Nuclear and hydro-electricity	1	3	10
Natural gas	—	<1	14
	100%	100%	100%

Source: Table 6(4)

6.12 Resource cost calculations suggest that the maximum benefit from natural gas will be obtained by its use in premium markets and, in particular, in place of town gas. Bulk gas sales to industry and possibly to electricity power stations will also be sought to build up quickly the total volume of sales.

6.13 Oil will be displaced through premature obsolescence of plant, its use in gasworks falling from 8·4 mtce in 1966 to an estimated 3 mtce in 1975. It is also thought that coal consumption in the gas industry would fall from 17M tons in 1966 to nil in the early 1970's. Oil and coal will therefore suffer in competition from natural gas in the bulk markets. The Government's estimates of trends in primary fuel consumption in 1975 are summarised in Table 6(4). The main assumptions underlying the estimates are:

that North Sea gas reserves would support a level of production at an average rate of 4,000 mcfd and that the price of the gas would be such that it could be sold;

that there would be no conversion of coal-fired power stations to oil;

that the second nuclear power programme would be fulfilled;

that oil tax would be at a rate of 2d. a gallon;

that no coal would be imported;

that Gross Domestic Product is assumed to grow at an average rate of 3% per annum (i.e. the same as in the past decade) as shown in Fig. 6(1).

TABLE 6(4)

Trends in Primary fuel consumption in the UK in million tons coal equivalent (mtce)

Sector	1957	1966		1975	
	mtce	mtce	Average % change pa 1957–66	mtce	Average % change pa 1966–75
Coal	212·9	174·7	−2	118	−4
Oil	36·7	111·7	+13	146	+3
Nuclear and hydro-electricity	1·7	10·2	+22	37	+15
Natural gas	—	1·1	—	49	+52
	251·3	297·7	+2	350	+2

Source: Fuel Policy White Paper, Cmnd. 3438, November 1967

6.14 The above estimates are the result of very detailed analyses made by the Ministry of Power in consultation with the nationalised fuel industries and with the oil companies. Nevertheless they are subject to considerable uncertainty and should be taken only as illustrating broad trends. The Government's policy is understood to be to lay down long-term planning guide-lines which can be modified from year to year in the light of experience and further knowledge.

6.15 Considerable uncertainty surrounds projections beyond 1975. The major factors that will determine the competitive position of the alternative fuels, and hence capital expenditure in each industry, include:

(a) The extent of further discoveries of natural gas and the price paid for it. Known recoverable reserves are estimated to amount to some 25 × 10^{12} cu. ft. which is sufficient to build up to a production rate of 3,000 mcfd within five years or so and to continue at that level for perhaps 15 years, thereafter gradually declining if no more gas is found. The rate of discovery so far has been very fast; the probability is that further reserves would be found and the industry continue to grow. The Government have accepted that a reasonable assumption for planning purposes is that production from the UK part of the North Sea could by 1975 reach 4,000 mcfd (equivalent to nearly four times the present consumption of town gas).

(b) Developments in technology and costs in the alternative fuels. The cost of generating electricity by nuclear power continues to fall, and Fuel Policy studies suggest that nuclear power could account for about one-quarter of our primary energy by 1980. Assuming total energy requirements continue to rise at 2% a year this would give the result shown in Table 6(5); however this is but an approximate estimate and the actual proportion of nuclear electricity would not materially affect the total demand for vessels in the electricity supply industry.

TABLE 6(5)

Possible growth in nuclear power 1975–80

	1975	1980	
	mtce	mtce	Average % change pa 1975–80
Total primary energy used	350	385	+ 2
Nuclear electricity	34	96	+23

6.16 It should be noted, however, that the prospects for individual fuels depend on the development of suitable appliances as well as on the cost of the fuel itself. The increase in gas sales between 1964 and 1967, accounted for by growing demand from the domestic and commercial markets, was related to the introduction of improved space and central heating appliances. Electricity sales, in contrast, may have suffered in recent years from a possible lack of competitive and flexible heating equipment.

6.17 From the above outline, two main conclusions may be drawn for fuel forecasts:

(a) The rapid growth in oil demand in the past decade and the rapid growth of natural gas in the next decade mark two distinct phases in the UK fuel economy. It is inappropriate to make forecasts for vessel demand in each fuel sector by assuming that past trends in total capital expenditure in each sector would continue, and each sector has therefore been considered separately.

(b) The pattern of demand to 1975 is already determined to a large extent by existing Government policy and capital expenditure programmes. For the period 1975–80 it is possible only to give the factors that will influence the course of events, some pointers to likely developments, and methods by which fabricators can assess for themselves the implications for pressure vessels as further information becomes available on the industries' development plans.

6.18 As much detailed information as possible has been sought on purchases of pressure vessels in the recent past, together with likely demand in the period up to 1972–3 which is the limit of the nationalised industries' five year development plans. Some approximate guidance is also given on vessel demand patterns for the period 1975–80.

Demand for vessels in gas plant

Past and forecast trends in gas sales

6.19 The future demand for vessels is largely dependent upon the demand for gas storage facilities, while gas storage requirements are related directly to trends in the sales of gas. An outline of past and planned developments in the gas industry is therefore given in the present section.

6.20 Table 6(6) gives detailed figures of the recent growth in gas sales and forecasts up to 1975, together with very tentative forecasts for the period 1976–80. The figures in the table show the very ambitious plans for the gas industry over the period 1968–75.

For the period 1976–80 a more modest annual increase of 8% per annum is taken, based on the assumptions that further discoveries of natural gas will be made, in which case the gas industry is likely to continue to grow at the expense of coal and oil in their industrial and domestic uses.

TABLE 6(6)

Actual and forecast growth in gas sales

Year	Annual demand for gas (M. therms)	Percentage increase over previous year (%)	
Actual			
1963–4	2,979	2 (5)	
1964–5	3,189	7 (8)	
1965–6	3,505	10 (9)	*
1966–7	3,775	8 (9)	
1967–8	4,222	12 (10)	
Forecast			
1968–9	4,700	11	
1969–70	6,000	27	
1970–1	7,250	21	
1971–2	8,250	14	
1972–3	9,100	10	
1973–4	11,000	21	
1974–5	13,300	21	**
1975–6	14,400	8	
1976–7	15,500	8	
1977–8	16,700	8	
1978–9	18,000	8	
1979–80	19,400	8	

* The bracketed figures are temperature corrected to allow for correction for the average ambient temperature

** Forecast figures are all at normal temperature

Sources: 1963–4 to 1972–3 The Gas Council, Annual Reports and Accounts, and Investment in Natural Gas, May, 1968

1973–4 to 1974–5 Fuel Policy White Paper

1975–6 to 1979–80 Tentative estimate of present economic survey

Demand for vessels in gas storage and distribution

6.21 During the period 1968–72, much of the industry's capital expenditure will be used to install the transmission and distribution system required for natural gas. By the mid-seventies this task will be nearly complete. It is estimated that by 1973 80% of gas supplies will be met from natural gas (virtually all the rest coming from oil gasification processes), and 61% of domestic consumers (over 8 million of the 14 million the industry expects to have in that year) will have their equipment converted to take it. Two factors combine to make gas storage requirements fairly modest in this transient period of very rapid growth:

(a) Natural gas has twice the calorific value of town gas (about 1,000 British Thermal Units per cubic foot) and therefore requires half the storage capacity for a given output of energy.

(b) In the early years, when a high rate of build-up has to be allowed for, it is expected that a measure of storage capacity will be available from some parts of the transmission and distribution system.

Both these factors should be of diminishing importance after 1975 when the industry's additional storage needs each year should come to bear a closer relationship to actual increases in sales achieved from year to year.

6.22 Future demand for vessels in the gas industry will be related to the industry's need to store gas to meet fluctuations in demand. There are several levels of storage in the gas industry depending upon the periodicity of the fluctuations in gas demand; three different levels are considered in the following paragraphs.

6.23 The first level of storage in the gas industry is that used to even out fluctuations in demand through the day and is the type of storage the industry has been concerned with until now. The industry's capacity for this type of storage amounts to about eight hours (or 30%) of total peak day demand, and is directly related therefore to the trend of the industry's sales at peak times of the year. There are no figures available for the trends in peak day demand, although the Gas Council has published figures of the maximum daily capacity in its Annual Reports (see Table 6(7)).

TABLE 6(7)

Maximum daily gas production capacity in the UK at year end

Year	Maximum daily capacity at year end (M. therms)	Percentage increase over previous year (%)
1963–4	14·1	—
1964–5	16·7	12
1965–6	18·5	11
1966–7	22·2	12
1967–8	28·3	27

This type of storage has been supplied hitherto by low pressure gasholders, by pressure vessels and by spare capacity in gas mains ('line pack'). At present this level of storage is still the responsibility of Area Boards, since the Gas Council will supply at a steady rate over 24 hours from the National Transmission system. Whilst storage for about 30% of the peak day demand for gas is open to pressure vessels, these vessels will have to compete with alternative forms of storage such as temporarily oversized gas mains and underground storage.

6.24 The second level of storage is used for meeting part of the demand on peak days. At present LNG is favoured for this purpose and is included in the Gas Council's capital development programme.

6.25 The third level of storage is that provided to even out fluctuations in seasonal demand, and this is the role of underground storage.

6.26 It is possible that the last two types of storage may be operated to cover part of the variation in demand during the day and thus reduce the need for storage at the first level provided specificially for this purpose. Since other, cheaper forms of storage are also under consideration, it would be unrealistic to assume an increasing requirement for pressure vessels for high pressure storage. Even in present circumstances, some Area Gas Boards regard this as an uneconomic solution and do not include it in their plans. No purchases of high pressure storage vessels are planned for 1972–3 although other forms of storage scheduled for the year total 40 million cubic feet. The current competitive position of pressure vessels, however, is indicated by details of Area Gas Boards' plans for installing additional storage capacity over the next few years as given in Table 6(8).

TABLE 6(8)

Planned additional storage capacity for Area Gas Boards

Year	Low pressure	High pressure	TOTALS
	(million standard cubic feet)		
1967–8	29·8	14·3	44·1
1968–9	32·8	34·5	67·3
1969–70	13·2	23·8	36·9
1970–1	16·7	27·0	43·7
1971–2	3·5	15·0	18·5
1972–3	5·0	—	5·0
TOTALS	100·9	114·6	215·5

Overall demand for gas plant

6.27 Estimates have been prepared for the total demand for gas plant, based on an assessment of demand in each of the gas industry's main areas of activity:

high pressure reforming plant,
high pressure storage,
LPG storage,
LNG storage,
terminals and above-ground installations,
replacement purchases of vessels.

6.28 Summary data has been assembled in Table 6(9) covering all the capital expenditure headings considered to involve pressure vessels, heat exchangers and tanks, as well as replacement purchases coming under revenue and not capital accounts. The only items excluded are the gas industry's past purchases of LNG storage tanks, a very specialised product supplied by only one or two firms, and past purchases of distillate storage tanks for which demand has now ceased. The forecasts are based on the gas industry's five year development plan but these expenditures have not all received Government approval and the final outcome could be different from that envisaged here. Although the overall capital sums involved may prove reasonably accurate, changing technology could make the estimates for individual items of gas plant, such as pressure vessels, completely wrong.

TABLE 6(9)

Estimated expenditure on pressure vessels, heat exchangers and tanks in the gas industry (£M)

Year	Gas manufacture high pressure reforming plant	Transmission and distribution				Replacement purchases of pressure vessels, heat exchangers and knock-out vessels	TOTALS (£M)
		High pressure storage	LPG storage	LNG storage	Terminals and above ground installations		
Current prices							
1962–3	1·6	—	0·3	n.a.	0·2	—	1·9
1963–4	1·6	—	0·6	n.a.		—	2·2
1964–5	1·6	—	0·7	n.a.		—	2·3
1965–6	2·8	0·3	0·5	n.a.		0·3	3·9
1966–7	4·4	1·2	0·6	n.a.		0·4	6·6
1967–8	5·1	1·1	0·4	n.a.	0·2	0·6	7·4
1967 prices							
1968–9	—	2·8	0·4	1·7	0·8	0·5	6·2
1969–70	—	1·9	0·2	1·7	0·4	0·5	4·7
1970–1	—	2·2	—	1·7	0·4	0·3	4·6
1971–2	—	1·2	—	1·7	0·3	0·2	3·4
1972–3	—	—	—	1·7	0·2	0·2	2·1

Source: Estimates given in paragraphs 6.30 to 6.42

6.29 Each of the areas listed in Table 6(9) is considered in detail section by section in paragraphs 6.30 to 6.42 below. The vessel expenditure figures in Table 6(9) are used in the overall summary given in Table 6(39).

TABLE 6(10)

Daily capacity of new plant brought into use in year (Mcfd)

Year	High pressure	Cyclic	Total oil gasification (including reforming)
1960–1	—	132·8	132·8
1961–2			
1962–3			
1963–4	1,165·7	190·0	1,355·7
1964–5			
1965–6			
1966–7	680·9	200·0	880·9
1967–8	1,074·0	300·0	1,374·0
1968–9	1,250·0	50·0	1,300·0
TOTALS	4,170·6	872·8	5,043·4 mcfd

Source: The Gas Council, Annual Report and Accounts (Appendix III, Section A)

High pressure reforming plant

6.30 The high pressure reforming capacity installed, in terms of daily capacity of new plant brought into use each year, is given for the period 1960–9 in Table 6(10).

6.31 The estimated purchases of vessels may be derived from Table 6(10) through use of the following data and assumptions:

> The total cost of high pressure reforming plant is approximately £15 for one 'therm per day' of installed capacity. As 1 therm equals 200 cu. feet, then the cost is approximately £0·075M per mcfd installed capacity.
> The vessel content of high pressure reforming plant as determined in interviews with contractors during the interview programme, is approximately 10·8% of equipment procured.
>
> The vessel content of cyclic reforming plant is assumed to be negligible, although some of the vessels would be built to a vessel design standard.
>
> A broad industry expenditure pattern is assumed, that is 50% of total plant cost is spent on equipment one year after the decision to invest and 50% is spent on site construction two years after the decision to invest (here decision to invest is equivalent to sanction).
>
> From the above, the vessel content of high pressure reforming plant is 5·4% of total cost, and equipment purchases would be made in the year preceding site construction and commissioning. This has the effect of shifting vessel expenditure back one year relative to the total plant cost.
>
> It is assumed that the expenditure for the period 1963–6 is spread equally between the three years.

6.32 Estimated purchase of vessels for high pressure reforming plants for the period 1962–8 are given in Table 6(11), as based on Table 6(10) and the assumptions listed in paragraph 6.31. The Gas Council's expenditure on manufacturing plant after 1968–9 will be concerned largely with the expansion or modification of existing plant, and is not likely to lead to significant purchases of pressure vessels, heat exchangers or tanks.

TABLE 6(11)

Estimated purchases of vessels for high pressure reforming plants

Year	Approximate total cost of high pressure reforming capacity installed		Estimated purchases of vessels (£M)
	(mcfd)	(£M)	
1962–3	—	—	1·6
1963–4	388·5	29	1·6
1964–5	388·6	29	1·6
1965–6	388·6	29	2·8
1966–7	680·9	51·0	4·4
1967–8	1,074·0	81·0	5·1
1968–9	1,250·0	94·5	—
TOTALS	4,170·6	313·5	17·1

High pressure storage

6.33 The figures for 1962–7 given in Table 6(9) for high pressure storage are derived from the Area Gas Boards' returns to the questionnaires sent out by the Gas Council for the economic survey. The figures relate to calendar years: 1962 expenditure has been allocated to 1962–3, and so on.

6.34 Figures for the financial years 1968–9 to 1972–3 are based on the Area Gas Boards' 1968 Capital Development Review, which gives probable but not firm plans for installing storage capacity. The expenditure estimates are based on an approximate total cost for high pressure storage of £100,000 per million cubic feet, with an estimated 80% pressure vessel content, according to Gas Council estimates. The approximate cost of vessels for the period 1968–73 is given in Table 6(12).

TABLE 6(12)

Future cost of vessels in high pressure gas storage

Year	Proposed new high pressure storage capacity (m. cu. ft.)	Approximate total cost (£M)	Approximate cost of vessels (£M)
1968–9	34·5	3·45	2·76
1969–70	23·8	2·38	1·90
1970–1	27·0	2·70	2·16
1971–2	15·0	1·50	1·20
1972–3	—	—	—

LPG storage

6.35 The figures for 1962–7 given in Table 6(9) for LPG storage are derived from the Area Gas Boards' returns as noted in paragraph 6.33 above.

6.36 The figures for 1968–9 and 1969–70 are the estimated cost of installing respectively 11,700 and 5,700 tons of LPG storage capacity. No further expenditure is planned.

LNG storage

6.37 Historical figures for purchases of LNG storage tanks are not available.

TABLE 6(13)

Future tentative expenditure on tanks and heat exchangers for LNG storage (£M)

Period	Tanks	Heat exchangers	TOTALS (£M)
1968–9 to 1972–3	6·6 (1·3 pa)	2·0 (0·4 pa)	8·6 (1·7 pa)
1973–4 to 1975–6	4·8 (1·6 pa)	1·6 (0·5 pa)	6·4 (2·1 pa)

6.38 LNG is currently favoured to meet part of the demand on peak days. The Gas Council's Capital Development Programme includes provision for expenditure on LNG tanks and heat exchangers both for vaporisation and in liquefaction plants, if required. Although plans are extremely tentative, the tank and heat exchanger content of this programme is estimated in Table 6(13).

Terminals and above-ground installations

6.39 The historical figure for terminals in Table 6(9) relates *only* to an estimated expenditure of £200,000 between 1962 and 1967 on heat exchangers and pressure vessels for the terminals at Canvey and Easington.

6.40 The forecast figures are based on the Gas Council's estimate that pig traps and heaters account for some 8% of expenditure in this category.

Replacement purchases

6.41 The figures for 1962–7 for replacement purchases in Table 6(9) are taken from Area Gas Boards' returns to the Gas Council as noted in paragraph 6.33. For heat exchangers the figures relate only to the replacement cost of the shell: the cost of the tubes is excluded.

6.42 The starred figures for 1968–9 to 1972–3 are present estimates based on the Gas Council's statement that replacement purchases are likely to remain at about the present level for two years or so and then to tail off.

Demand for vessels in electricity generating plant

Past and forecast trends in electricity sales

6.43 The Government's policy for future electricity power stations lays down that the industry should choose the fuel that will enable it to supply electricity at the lowest system cost consistent with security of supply and load balancing. There is still considerable debate as to which type of fuel should be chosen for the next generation of power stations and if, as seems likely, the emphasis on nuclear stations increases, further debate will arise as to which particular reactor type will be used. Nevertheless, the pressure vessel costs in power stations discussed in paragraph 6.48 are not expected to vary significantly with the various alternatives under consideration and these figures may therefore be used to predict the demand of vessels from estimates of the growth in installed capacity of generating plant.

6.44 The industry's plans for new capacity are based on meeting the forecast maximum demand in winter in average cold spell conditions (roughly day-time freezing) plus a 17% gross planning margin to allow for errors in load forecasting, variations in weather conditions and non-availability of plant at the time of peak load. The gross planning margin was raised from 14% to 17% in 1964–5. Recent increases in the maximum load are given for the CEGB in Table 6(14), including temperature adjusted figures. Temperature adjusted data for the SSEB were unavailable and are therefore not shown.

TABLE 6(14)

Maximum potential load* as reported by CEGB (ie excluding Scotland)

Year	Maximum potential load (MW)*	Per-cent change on previous year	
		Actual	Temperature adjusted**
1961–2	27,856	+13·9%	+8·5%
1962–3	32,100	+15·2	+8·1
1963–4	30,488	− 5·0	+4·6
1964–5	31,779	+ 4·2	+5·2
1965–6	36,007	+13·5	+6·0
1966–7	34,530	− 4·3	+2·7

Source: Annual Reports of the CEGB

* The maximum potential load is calculated by adding, to the maximum demand actually met, estimates of any relief obtained from frequency or voltage reduction and disconnection of supplies

** To obtain the underlying trend in demand, adjustments are made to the maximum load to average weather conditions and to a standard number of working days for each month

6.45 The forecasts for electricity demand for the period 1967–81 are given in Table 6(15). The overall average annual increase in maximum demand of 6·2% per annum illustrates that the growth in demand is likely to be below the 9% per annum average annual increase in electricity sales between 1953–63, but very slightly above the 6% per annum average annual increase between 1963–67. Very approximate estimates for growth in electricity demand are given in Table 6(16) for the period 1966–7 to 1973–4, and are based on the approximate growth figures in Table 6(15).

TABLE 6(15)

Maximum demand for electricity in average cold spell conditions

Area	Maximum demand (MW)		
	1966–7 (Actual)	1973–4 (Forecast)	1980–1 (Forecast)
CEGB	—	54,000	80,000
SSEB	—	7,340	12,591
TOTALS	39,991 ——→	61,340 ——→	92,591
	(6·35% pa)	(6·1% pa)	

Growth in electricity generating capacity in period 1961–68

6.46 The maximum demand for electricity generating plant (or generating capacity) may be roughly estimated from Table 6(16), by allowing for the 17% gross planning margin between capacity and maximum electricity demand (see paragraph 6.44). The magnitude of the demand for pressure vessels is associated with new generating capacity.

6.47 According to the Fuel Policy White Paper and relevant annual reports the capacity of generating plant at March 1967 was as follows:

CEGB	38,468 MW
SSEB	2,730 MW
TOTAL GB	41,198 MW

An estimate of the growth of future plant capacity may be made by assuming that the figure of 17% gross planning margin of capacity over demand would be rapidly attained over a period of several years and held at 17% thereafter; this follows from the rapid build-up in vessel orders in the period 1961–6. It may be noted that the actual gross planning margin in 1966–7, according to the figures in Table 6(15) and this paragraph, would be greater than 3% when the generating capacity of the North of Scotland Hydro Electric Board is taken into account. Very approximate estimates in the assumed growth of electricity generating capacity are illustrated in Table 6(16).

TABLE 6(16)

Assumed growth in electricity generating capacity in Great Britain

Year	Approximate maximum electricity demand (MW)	Assumed gross planning margin (%)	Assumed estimated capacity (MW)
1966–7	39,991	3	41,198
1967–8	42,500	10	46,700
1968–9	45,200	13	51,000
1969–70	48,100	17	56,300
1970–1	51,200	17	60,000
1971–2	54,500	17	63,700
1972–3	58,000	17	68,000
1973–4	61,340	17	71,600

Sources: Table 6(15) and paragraphs 6.44 and 6.47

Demand for vessels in electricity generating plant

6.48 The great majority of pressure vessels and tanks are used in the generation of electricity rather than in its transmission; it is not suitable therefore to apply pressure vessel ratios (relating to generation) to total figures for capital expenditure. Power stations take some five years to build and the expenditure pattern detailed in paragraph 6.31 based on a two year cycle does not apply. It is understood that expenditure on the manufacture of heavy pressure vessel equipment might be spread mainly over the middle three years of the construction period while expenditure on construction would continue throughout the whole of the five year period, the plant being commissioned in the fifth year (the plant thus not being added to 'capacity' data until the fifth year). Estimates have been obtained for the pressure vessel ratios which could be applied either to the total capital cost or to the installed capacity of a power station. Analyses made by the CEGB in 1968 suggest that for nuclear or coal fired power stations expenditure on pressure vessels (excluding heat exchange surfaces in the case of boilers, feedheaters, etc.) and tanks amounts to some £750,000–£900,000 for each

660 MW unit. This figure can be related either to cost or capacity as indicated in Table 6(17). Technical variations in both conventional and nuclear power stations can have the effect of changing the vessel content between the limits given in Table 6(17) for both these types of power stations, according to the type of conventional or nuclear power station involved. An approximate average index for vessel cost of £1,250 per MW of new installed capacity is therefore assumed.

TABLE 6(17)

Cost of vessels per megawatt for electricity generating stations of the 660 MW type (including installation) in 1967

Plant item	Coal fired	Nuclear (AGR)
	£'000	
Drums	150	—
Headers	600	500
Feedheaters—pressure vessel content	100	100
Other pressure vessels	8	110
Water/oilstorage tanks	25	25
Total vessel costs	883	735
Vessel cost per MW:	1·35	1·15
Vessel cost as per cent of total cost of station	2%	1%

6.49 Direct estimates of vessel purchases by the CEGB, the SSEB and the UKAEA have been noted in Table 6(18) for the period 1961–2 to 1967–8. The purchases figures in brackets refer to incomplete data for the next few years. The vessel expenditure figures for 1961–8 in Table 6(18) are used in the overall summary given in Table 6(39).

6.50 To outline very approximately the effect that the five year 'approval-to-commissioning' cycle has on vessel expenditure patterns, it is assumed that expenditures on vessels are averaged about the third year in the five year cycle, suggesting that vessel expenditure falls approximately two years in advance of commissioning. The figures should be used only as a very approximate indication of how the pattern of vessel expenditure may fall in the next few years, and are given in Table 6(19). It is stressed that an annual growth rate in electricity demand of about 6% per annum is assumed, as well as the rapid achievement of the 17% gross planning margin of capacity over demand. The approximate vessel expenditure figures for 1969–72 in Table 6(19) are used in the overall summary given in Table 6(39).

Forecast growth in electricity generating capacity for period 1973–81

6.51 The longer term forecast may tentatively be estimated on the basis of the maximum demand data in Table 6(15), together with the gross planning margin in capacity of 17% as noted in paragraph 6.44. The implied electricity generating capacity requirements are given in Table 6(20).

TABLE 6(18)

Estimates of vessel purchases for electricity generating and nuclear plant in Great Britain: 1961–68

Year	Vessel purchases as estimated by CEGB & SSEB (£M)	Vessel contracts as estimated by UKAEA (£M)
1961–2	2·4	0·57
1962–3	4·4	0·23
1963–4	5·8	0·11
1964–5	7·0	0·08
1965–6	7·7	0·10
1966–7	6·1	0·31
1967–8	4·8	0·63
1967 *Prices*		
1968–9	(3·2)	(0·12)
1969–70	(1·7)	—
1970–1	(1·7)	—

Notes: The second column is the estimated purchases of pressure vessels and tanks by the CEGB and the SSEB under the approved building programme (excluding Hartlepool). Data for 1961–7 is in current prices and is believed to be complete. Data for 1968–71 is in 1967 prices and the brackets indicate incomplete figures as orders will not have been placed for all the equipment concerned. It is understood these figures probably exclude vessels associated in power generation for smelters. This would have but little effect on the annual vessel purchases figures, as one-sixth of (e.g. Hunterston B) will be for smelters (i.e. 210 MW for smelting). The figures give expenditure estimates for the year in which it is expected to take place and include immediate installation costs (instrumentation, electrics, etc.) but not civil engineering work

The third column is the value of contracts placed for pressure vessels and tanks as estimated by the UKAEA. Expenditure on vessels would probably fall within a reasonable time following the placing of the contracts

TABLE 6(19)

Assumed vessel expenditure for electricity generating plant in Great Britain: 1965–72

Year	Additional net capacity assumed (MW)	Loss of capacity due to obsolescence (MW)	Additional new (gross) capacity assumed = (b) + (c) (MW)	Assumed vessel expenditure derived from (d) (£M)
(a)	(b)	(c)	(d)	(e)
1965–6	—	—	—	7·7
1966–7	—	—	—	6·1
1967–8	5,500	500	6,000	7·4
1968–9	4,300	500	4,800	5·4
1969–70	5,300	500	5,800	5·4
1970–1	3,700	500	4,200	6·1
1971–2	3,700	500	4,200	5·2
1972–3	4,300	500	4,800	—
1973–4	3,600	500	4,100	—

Notes: Column (b) has been obtained from the last column of Table 6(16)

(c) is an approximate allowance for further new capacity required by depletion of existing capacity due to obsolescence. This is about 500 MW/per annum.

(d) is columns (b)+(c), and represents the gross new capacity required

(e) has been approximately estimated from (d) by assuming vessel cost is £1,250 per MW of new installed capacity and that expenditure may be agglomerated to occur two years before commissioning of plant (see paragraph 6.48). Figures in 1967 prices

TABLE 6(20)

Approximate electricity generating capacity requirements

Area	Generating capacity requirement estimates (MW)		
	1966–7 (Actual)	1973–4 (Estimated)	1980–1 (Estimated)
CEGB	38,468	—	—
SSEB	2,730	—	—
TOTALS	41,198	72,000	109,000

6.52 The electricity generating capacity (including Hartlepool) on the building programme as at 1968 is about 32,500 MW, and this would be commissioned by 1973–4. Depletion of generating capacity of about 0·5 MW per annum occurs due to plant obsolescence or closure. The balance of capacity as at 1973–4 would therefore approximately be 41,200 MW minus 3,500 MW (obsolescence) plus 32,500 MW which equals 70,200 MW. During the period 1973–4 to 1980–1 a further 3,500 MW would become obsolete, implying a total new generating capacity to be installed of about 42,300 MW during this period. Assuming the new capacity is spread approximately evenly over this period, it implies a requirement for about 6,000 MW new capacity each year between 1973–4 and 1980–1 (allowing for plant obsolescence); or assuming the new capacity distributed approximately in phase with the increase in demand, it implies a requirement of about 4,700 MW in 1973–4 rising to 7,300 MW in 1980–1.

6.53 In paragraph 6.48 it is assumed that a mean index for vessel cost would be £1,250 per MW of new installed capacity. The 6,000 MW per year thus represents an expenditure of about £7·7M on vessels during each year between 1971–2 and 1978–9, or £6·1M in 1971–2 rising to £9·5M in 1978–9 (bearing in mind the 'phase advance' between vessel expenditure and plant commissioning). The latter figures are included in the overall summary in Table 6(39) as being representative of figures for 1977.

6.54 It is extremely uncertain as to how the actual increases in capacity will be timed in the future, and fabricators of vessels with interests in the construction of generating stations should keep themselves fully informed as to the likely trend in approvals for future electricity generating capacity.

Demand for vessels in oil refinery plant

Past and forecast trends in oil sales

6.55 Estimates of UK domestic oil consumption have been given in Table 6(4); these indicate that home demand is estimated at 66M tons in 1966 and at 86M tons in 1975 (using a conversion factor of 1·7 tons of coal = 1 ton of oil), this represents a growth rate of 2·7% pa.

6.56 After 1975 there would probably be a more modest growth in oil consumption, and a growth rate in demand for oil close to that for energy as a whole (2% pa) might be a reasonable assumption for this period. Little, if any, addition would be made to the UK capacity in oil gassification plant after 1969–70, and this represents a substantial sector of demand for oil that would cease to grow further after 1970. Whilst oil is a major feedstock for the organic chemical industry, this use represents only a small proportion of total consumption of oil (estimates are given in Table 6(21)).

TABLE 6(21)

Proportion of petroleum output consumed by the world chemical industry

Year	Proportion (%)
1968	2·5%
1985	5%
2000	12%

Source: N. A. Iliff, SCI Presidential Address, 19.7.68

Growth in oil refining capacity

6.57 Forecasts of total UK refining capacity for the period 1968 to 1970 (with the actual figures for 1963, 1966 and 1967) are shown in Fig. 6(2). The forecasts for 1968–70 have been compiled from individual company forecasts and are quoted in PPWP Report No. 3. About 92% of annual capacity in refining could normally be made available as output. This implies a possible output of 106M tons pa in 1970, against an estimated home demand in fuel sales of oil products of at least 75M tons in the same year.

6.58 The above figures suggest that some capacity in excess of that required for home demand may continue to exist for some while in the future, and this would permit substantial exports of oil products well beyond 1970. In such circumstances no more than about 10M tons pa of new refining capacity may be commissioned in the period 1970–5, following which the *average* annual increase in refinery capacity might keep in step with growth in total energy consumption (see paragraph 6.56), leading to a capacity of about 138M tons pa by 1980. These very tentative estimates are shown in Fig. 6(2), together with the annual additions to oil refining capacity which reached a peak of 18M tons pa capacity added in 1967–8. The annual additions to capacity might then drop rapidly to 2M tons pa in 1970–5 and 2·6M tons pa in 1975–80, although considerable growth in non-fuel uses for oil would considerably raise these figures. These are approximate figures only as consideration has not been given towards future problems of refinery balance in terms of product ranges required in response to changes in future market conditions; neither has consideration been given towards changes in the proportions of the market held by different oil refining companies.

6.59 Inspection of Fig. 6(2) indicates the rapid rise in oil refining capital expenditure between 1965–7, closely followed by the rapid rise in annual additions to refinery capacity, peaking in 1967–8.

6.60 Assuming an average construction figure of £7 per ton of oil refining capacity, the above suggests annual *new* plant expenditure figures of £14M between 1970–5 and £18M between 1975–80. These figures exclude any allowance for repairs and replacements; estimates based on the 3rd PPWP Report suggests this to be about 15% of total capital expenditure. By inspection of the Blue Book figures for mineral oil refining capital investment, the average expenditure for 'plant and machinery' is about 82% of the total expenditure in any one year. The total capital expenditure figures thus derived are given in Table 6(22).

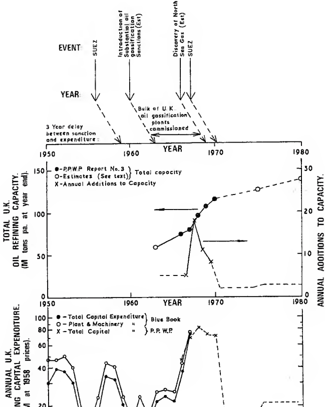


FIG. 6(2). Mineral oil refining: annual expenditure (1958 prices) and growth in refining capacity

TABLE 6(22)

Estimated annual expenditures on mineral oil refinery plant including repairs (at 1967 prices)

Period	Plant and machinery expenditure (£M pa)	Total capital expenditure (£M pa)
1970–75	16·0	19·6
1975–80	20·6	25·2

6.61 Also shown in Fig. 6(2) for information are the approximate times at which a few events of importance to the oil refining industry occurred. The assumption is made that a three year delay occurs between plant sanction and its associated capital expenditure.

Demand for vessels in oil refinery plant

6.62 The difference in patterns of expenditure between new oil refineries and modifications or repairs to existing refineries is not known. Furthermore, there is considerable variation in the 'vessel cost to plant and machinery expenditure' percentage depending on the type of refinery built and any market estimates based on a 'typical' figure are necessarily approximate. The petrochemical elements of refinery complexes are normally included within the chemical industry figures. This follows from the normal practice of oil companies in segregating the various elements of the complexes along organisational lines, having separate divisions/companies for the refining and petrochemical elements.

TABLE 6(23)

Estimates for vessel expenditures in oil refinery plant during the period 1961–80 (£M)

Year	Vessel expenditures (£M): 16%—23%
Current prices	
1961	3·0— 4·4
1962	2·4— 3·5
1963	3·7— 5·3
1964	4·0— 5·8
1965	3·8— 5·5
1966	6·9— 9·9
1967	14·1—20·2
1967 *prices*	
1968	13·3—19·1
1969	11·8—17·0
1970	11·3—16·3
1972	2·6— 3·7
1977	3·3— 4·7

6.63 It is believed that the percentage figure for vessels increases with increase in unit size of the refinery built, and that the historic trend of ever increasing unit size is likely to continue in the long term. However, bearing in mind that some spare refining capacity may exist in the UK in 1970, and that a fairly modest growth rate in oil demand is anticipated thereafter, any new capacity installed in the UK in the period 1970–80 may be in moderate-sized plants. The changing pattern of demand could lead to problems of refinery balance in the future which could be met partly by investment in additional cracking plant. Future demand for oil refineries during 1970–80 may also depend upon the oil industry's ability to gain further export outlets for its products, as well as on oil's performance in the rapidly changing energy demand market in the UK.

6.64 Examples of the analyses of costs of average large oil refineries have been examined (sources: 1st PPWP Report and the present economic survey interview programme), and these suggest an average 'vessel to plant and machinery expenditure' percentage of 19·5%, in a range of such percentages from 16% to 23%. Estimates based on this range of percentages are given in Table 6(23); these are used in summary Table 6(39).

Demand for chemical process vessels: estimates for period 1962–7

Introduction

6.65 Two different methods have been used to derive vessel demand arising from expenditure on chemical process plant. These are both different from the methods used for the gas, electricity and oil plant demand sectors which are based on estimated growths in sales of gas, electricity and oil. The chemical process industry comprises a number of chemical sub-sectors, each of which is likely to have a different growth rate dependant upon its product. Furthermore, each chemical product is produced by a process plant which is likely to have a different capital cost breakdown; thus the vessel cost to total plant and equipment cost percentages for process plants producing different chemical products are likely to be different (by a substantial margin). In the first method each chemical sub-sector has been considered individually, and a pattern of expenditure has been derived for vessels for all chemical process plant by summing the demand for vessels in each chemical sub-sector (this is the method detailed in paragraphs 6.66 to 6.74). The second method is based on the extrapolation of a survey undertaken by the CIA and the economic survey team (detailed in paragraphs 6.75 to 6.77).

Demand for vessels in chemical process plant: method 1

6.66 For the purposes of the first method the chemical industry has been divided according to the sub-sectors given in 'Chemical Age'. Altogether 11 main chemical sub-sectors are considered, and these are listed in Table 6(25).

6.67 The method used for estimating the overall vessel demand in the chemical industry for the period, 1964–7, essentially consists of the following seven steps:

(a) The total expenditure for all chemical process plant falling in each year is taken as the starting point;

(b) A table is constructed in which data for equipment expenditure is derived from (a);

(c) An estimate is prepared for the percentage of equipment expenditure in (b) that falls to each chemical sub-sector;

(d) The equipment expenditure falling to each chemical sub-sector is obtained from (b) × (c);

(e) An estimate is prepared of vessel expenditure to equipment expenditure percentages for each of the chemical sub-sectors;

(f) The vessel expenditure for each chemical sub-sector is obtained from (d) × (e);

(g) The vessel expenditure for the chemical industry is obtained by summing the vessel expenditures for all chemical sub-sectors determined at (f).

6.68 Two main sources were used for total expenditure on plant and machinery: the National Income and Expenditure Blue Book data for 1956–65 in Table 6(1), and the total capital expenditure data from the 3rd Report of the Process Plant Working Party for 1967–70. A table has been constructed based on the assumptions first noted in the demand section for the gas industry: that is, total sanctions on plant and machinery in year 0 falls equally divided between equipment expenditure in year 1 and construction expenditure in year 2. (It should be noted that total *capital* investment is the sum of expenditures on: (i) plant and machinery, (ii) other new buildings and works, and (iii) vehicles.) It is assumed that total expenditure on plant and machinery in year 2 is the sum of the construction expenditure in year 2 (calculated as half sanction for year 0) and the equipment expenditure in year 2 (calculated as half sanction for year 1).

6.69 Table 6(24) shows the division of total plant and machinery expenditure into equipment expenditure and construction expenditure (paragraph 6.67(b) refers).

TABLE 6(24)

Estimated division of total plant and machinery expenditure into equipment expenditure and construction expenditure

Year	Sanction (£M)	Equipment expenditure (£M)	Construction expenditure (£M)	Total expenditure on plant and machinery (£M)
(a)	(b)	(c)	(d)	(e)
Current prices				
1956	88	66	29	95
1957	140	44	66	110
1958	78	70	44	114
1959	114	39	70	109
1960	134	57	39	96
1961	114	67	57	124
1962	86	57	67	124
1963	182	43	57	100
1964	145	91	43	134
1965	260	90	91	181
1966	170	130	90	220
1967	125	43 (85*)	130	173
1967 *prices*				
1968	245	105 (63*)	85	190
1969	195	123	63	190 (186)
1970	na	98	122	200 (220)

Notes: Column (b) The figures for 1965–69 are based on those in the PPWP 3rd Report, with the deduction of £40M to allow for expenditure on vehicles and other new buildings and works.

(c) £42M has been substracted from equipment expenditure in 1967 and added to the figure for 1968. The starred figures in brackets are the unadjusted figures for those years

(e) The figures for 1956–67 come from the National Income and Expenditure Blue Book. For 1967 onwards only total capital investment estimates are available made up of three items: plant and machinery, other new buildings and works, and vehicles. Expenditure on the last two averaged some £40M a year between 1960 and 1966. This amount has therefore been deducted from the total expenditure figures from 1967 onwards given in the 3rd Report of the Process Plant Working Party. For the years 1968–70 minor differences in the figures arise between the values given (from the 3rd PPWP Report) and those given in brackets (derived from the method of construction of the table). In part, they are likely to be accounted for by fluctuations in expenditure on fixed assets other than plant and machinery. The discrepancy of +10% for 1970 is not considered important: estimates for that year are likely to be substantially revised

6.70 In its annual surveys of the chemical industry *Chemical Age* gives estimates of expenditure on plant for each sector of the chemical industry. These figures are given for all projects (i.e. those completed in the past year and those still in hand) and for projects in hand. From these tables it has been possible to derive annual figures for completions and to apply the resulting expenditure proportions to equipment purchases *for the year before*. The figures cannot be taken back beyond 1965: only total figures were published in earlier years in *Chemical Age*. Table 6(25) gives the estimated annual figures for plants completed in each of the years 1965–7 by chemical sub-sector.

TABLE 6(25)

Chemical plants completed by year (£M)

Chemical sub-sector	Plants completed in:			Plants in hand 1967
	1965	1966	1967	
Heavy organics	31·33	38·68	46·49	156·00
Synthetic fibres	17·60	15·10	47·45	47·20
Fertilisers	16·20	45·32	39·30	21·00
Inorganics	7·96	13·84	26·90	26·11
Plastics and resins	6·41	8·98	17·50	16·44
Pharmaceutical	8·00	11·08	9·99	6·94
Industrial gases	1·98	3·21	7·80	6·66
Synthetic rubber	—	2·60	4·23	8·60
Coal chemicals	0·97	0·52	5·08	3·40
Dyestuffs	0·98	2·16	4·19	1·28
Miscellaneous	7·44	7·79	6·85	11·32
TOTALS	98·84	149·28	215·79	304·94

6.71 The figures in Table 6(25) have been recast in the form of percentages of plant completions for each of the chemical sub-sectors. The resulting percentages are given in Table 6(26).

TABLE 6(26)

Percentages of plant completions (%)

Chemical sub-sector	Plants completed in:			Plants in hand 1967
	1965	1966	1967	
Heavy organics	32	26	22	51
Synthetic fibres	18	10	22	15
Fertilisers	16	30	18	7
Inorganics	8	9	12	9
Plastics and resins	6	6	8	5
Pharmaceutical	8	8	5	2
Industrial gases	2	2	4	2
Synthetic rubber	—	2	2	3
Coal chemicals	1	1	2	1
Dyestuffs	1	1	2	1
Miscellaneous	8	5	3	4
TOTALS	100	100	100	100

6.72 The assumption is made that equipment expenditure in each chemical sub-sector may be obtained by applying the percentages of plant completions in any one year to the total equipment expenditure in the previous year. In this manner the percentages of plant completions in Table 6(26) for the period 1965–7 have been applied to the equipment expenditure data in column (c) of Table 6(24) for the period 1964–7. The resulting equipment expenditure patterns are given in Table 6(27).

TABLE 6(27)

Equipment expenditure by chemical sub-sector (£M)

Chemical sub-sector	1964	1965	1966	1967
Heavy organics	29·1	23·4	28·6	21·9
Synthetic fibres	16·4	9·0	28·6	6·5
Fertilisers	14·6	27·0	23·4	3·0
Inorganics	7·3	8·1	15·6	3·9
Plastics and resins	5·5	5·4	10·4	2·1
Pharmaceutical	7·3	7·2	6·5	0·9
Industrial gases	1·8	1·8	5·2	0·9
Synthetic rubber	—	1·8	2·6	1·3
Coal chemicals	0·9	0·9	2·6	0·4
Dyestuffs	0·9	0·9	2·6	0·4
Miscellaneous	7·3	4·5	3·9	1·7
TOTALS	91	90	130	43

6.73 The vessel contents in equipment expenditures for each chemical sub-sector were derived from the economic survey interview programme and other sources. The estimated value of vessels as a proportion of equipment expenditure in each of the chemical sub-sectors is given in Table 6(28).

TABLE 6(28)

Vessel content in equipment expenditure by sub-sector (%)

Chemical sub-sector	Vessel content in *equipment* expenditure (%)
Heavy organics	23·1
Synthetic fibres	17·3*
Fertilisers	19·4
Inorganics	15·0
Plastics and resins	14·0
Pharmaceutical	13·0
Industrial gases	24·0
Synthetic rubber	14·2
Coal chemicals	11·0
Dyestuffs	21·3
Miscellaneous	10·0**
Weighted mean for industry	18·5

* Three-quarters of the cost of synthetic fibres plant is estimated for use in the production of intermediates and one-quarter for the production of fibres. The heavy organic percentage has been multiplied by 0·75 to derive the synthetic fibres 'vessel content in equipment expenditure' percentage.

** Headings that come under 'miscellaneous' include:

vegetable and animal oils and fats	6·0%
soaps	7·0%
polishes	4·5%
gelatine and adhesives	3·5%

However, the miscellaneous heading probably contains a number of plant items that could more appropriately be included in one of the named sub-sectors in Table 6(28). An approximate value of 10% has therefore been taken as a reasonable estimate for miscellaneous.

6.74 The vessel expenditure for each chemical sub-sector is obtained directly by multiplying the equipment expenditure patterns in Table 6(27) by the appropriate sub-sector vessel content percentage in Table 6(28). The total vessel expenditure is obtained by adding vessel expenditures for each sub-sector, and this is given in Table 6(29).

TABLE 6(29)

Vessel expenditure by sub-sector and for the whole chemical industry (£M) (current prices)

Chemical sub-sector	1964	1965	1966	1967
Heavy organics	6·7	5·4	6·6	5·1
Synthetic fibres	2·8	1·6	4·9	1·1
Fertilisers	2·8	5·2	4·5	0·6
Inorganics	1·1	1·2	2·3	0·6
Plastics and resins	0·8	0·8	1·5	0·3
Pharmaceutical	0·9	0·9	0·8	0·1
Industrial gases	0·4	0·4	1·2	0·2
Synthetic rubber	—	0·3	0·4	0·2
Coal chemicals	0·1	0·1	0·3	—
Dyestuffs	0·2	0·2	0·6	0·1
Miscellaneous	0·7	0·4	0·4	0·2
Whole chemical industry	16·5	16·5	23·5	8·5

Demand for vessels in chemical process plant: method 2

6.75 The Chemical Industries Association conducted a sample survey of its members on behalf of the economic survey. A questionnaire was sent out asking companies about purchases of pressure vessels, heat exchangers and tanks made by them or on their behalf between 1962 and 1967. The CIA sent out 26 questionnaires, all of which were returned. The largest chemical company in the UK filled in separate questionnaires sent to them directly and the results of these 27 returns were adjusted for the chemical industry as a whole by the CIA and the survey team. The CIA estimate that the companies making the returns accounted from 50% of total chemical industry capital expenditure in the earlier years to 74% in the later years. Due to uncertainty in the extrapolation of purchasing habits (proportions imported and bought through contractors) of the 50% to 74% sample, the extrapolated results of the CIA survey as given in Table 6(30) are subject to substantial margins of error. In addition, the trend from year to year may be misleading as a result of these margins of error.

6.76 While estimates given for pressure vessels and heat exchangers take into account the different sources of supply, tanks may be under-estimated, as purchases through contractors are not explicitly taken into account. The survey included provision for replacement demand as well as new demand.

6.77 The most interesting features of the results obtained from the sample survey on pressure vessels and heat exchangers are linked to the relative positions of foreign purchases made directly by final users and the level of total procurement which is done through contractors for the chemical industry. These percentages are given in Table 6(31). The average amount of purchases of pressure vessels and heat exchangers made *directly* abroad by final users during the period studied is 8% in a range of 2% to 14%. On the other hand, contractors have supplied an average of 54% (in a range of 40% to 62%) of total procurement of pressure vessels and heat exchangers to the chemical industry, this being obtained from both UK and foreign fabricators.

TABLE 6(30)

Estimated pressure vessel, heat exchanger and tank procurement in the chemical industry during the period 1962–67 (current prices £M)

(Estimate extrapolated from sample survey of industry)

	1962	1963	1964	1965	1966	1967 Estimated
(*a*) *Pressure vessels*						
Total delivered costs of purchase direct from UK manufacturer	2·10	1·79	2·84	3·85	4·40	3·57
Total (cif) costs of purchases direct from foreign manufacturer	0·96	0·08	0·92	0·69	0·71	0·76
Estimated costs of PVs bought through contractors in UK	2·25	2·30	4·29	3·53	4·63	3·03
Total procurement	5·31	4·17	8·05	7·80	9·74	7·36
(*b*) *Heat exchangers*						
Total delivered costs of purchases direct from UK manufacturer	0·89	0·62	1·33	1·21	1·45	1·21
Total (cif) costs of purchases direct from foreign manufacturer	0·15	0·06	0·26	0·24	0·36	0·31
Estimated cost of HEs bought through contractors in UK	1·78	1·60	4·34	0·36	4·80	3·69
Total procurement	2·82	2·28	5·93	1·81	6·61	5·21
(*c*) *Tanks* (excluding erection costs)						
Total delivered cost of fixed tanks	3·19	3·30	3·40	3·50	3·93	3·25
Total delivered cost of road/rail tanks	0·01	0·04	0·17	0·10	0·03	0·05
Total delivered costs of demountable tanks	0·09	0·39	1·44	0·21	0·28	0·28
Total procurement	3·29	3·73	5·01	3·81	4·23	3·58
TOTAL VESSEL PROCUREMENT	11·42	10·18	18·99	13·42	20·58	16·15

TABLE 6(31)

Percentages of pressure vessel and heat exchanger procurements by direct foreign purchases and by purchases through contractors during 1962–1967

Year	Total pressure vessel procurement		Total heat exchanger procurement		Total pressure vessel *and* heat exchanger procurement	
	direct foreign	by contractors*	direct foreign	by contractors*	direct foreign	by contractors*
1962	18·0%	42·0%	5·0%	63·0%	14·0%	50·0%
1963	2·0	55·0	3·0	73·0	2·0	60·0
1964	11·0	53·0	13·0	20·0	8·0	62·0
1965	9·0	45·0	5·0	70·0	10·0	40·0
1966	7·0	48·0	4·0	73·0	7·0	58·0
1967	10·0	41·0	6·0	71·0	9·0	53·0
Mean 1962–67	10·0	47·0	6·0	67·0	8·0	54·0

* Total procurement through contractors (whether purchased in UK or imported)
Source: Table 6(30)

Comparison of vessel expenditure estimates: methods 1 *and* 2

6.78 It is of interest to compare the vessel expenditure estimates prepared by methods 1 and 2: this is given in Table 6(32).

TABLE 6(32)

Vessel expenditure estimates for chemical industry (current prices)—(£M)

Year	Subsector analysis estimates from Table 6(29)	CIA survey estimates from Table 6(30)
1962	—	£11·4M
1963	—	10·2
1964	£16·5M	19·0
1965	16·5	13·4
1966	23·5	20·6
1967	8·5	16·2*

* Estimated figure, other figures relate to actual purchases

6.79 The two sets of figures in Table 6(32) are not directly comparable. For example, the CIA estimates include replacement purchases of pressure vessels (possibly about 5% of annual expenditure on pressure vessels) and of heat exchangers (possibly about 8% of annual expenditure on heat exchangers). The estimates from Table 6(29) do not contain any allowance for replacements. Without more detailed knowledge than is available, it is not possible to indicate which is the more accurate series of expenditure figures; both methods are liable to substantial errors. Nevertheless, the totals for the two series of figures for the three year period 1964–6 agree to within 6%, suggesting that some of the differences in the annual figures could arise from differences in the effective accounting periods used in the two series. The figures suggest that demand for vessels by the chemical industry was of the order of £13–19M in 1964 and 1965, rising to £20–23M in 1966. The fabrication industry's decreasing order books in 1967 suggest that demand fell much more sharply in that year than is shown in the CIA figures.

Demand for chemical process vessels: estimates for period beyond 1967

Introduction

6.80 In considering forecasts of future growth in the chemical industry, it is believed to be a matter of opinion as to which particular assumption should be selected in order to predict this growth. The future demand for vessels relies largely on the future fortunes of the chemical industry, which itself relies largely on the developing and complex pattern of demand for chemical products of both intermediate and final product status.

6.81 A variety of methods are available for the tentative estimation of future demand for vessels. Two simple methods have been chosen for the purposes of the economic survey and these are detailed below. The methods produce wide-ranging forecasts, and this illustrates the problems besetting attempts to forecast meaningfully and with accuracy in this sector.

Forecast demand for vessels in chemical process plant: method A

6.82 Fig. 6(3) shows the growth in total capital expenditure in the chemical industries of the UK, the USA and Federal Republic of Germany, all in *current* prices. The broad pattern of growth accompanied by fluctuations is common to the industries of these three countries, the fluctuations also appear to be in-phase. The rates of growth for the period 1955–66 are approximately:

Federal Republic of Germany	10·2% pa
USA	7·4% pa
UK	5·4% pa

6.83 Fig. 6(4) shows the growth of the UK chemical industry expenditure in more detail for the period 1950–66 in *constant* (1958) prices. The 'total capital expenditure' in any one year equals 'plant and machinery' expenditure, plus expenditure on 'other new buildings and works' and 'vehicles'. The two last named expenditures increased during 1950–55 to achieve a constant level of £40M from 1955 onwards.

6.84 For method A forecast the assumption is made that the item 'plant and machinery' would continue to grow at about 5·2% pa in constant (1958) price terms. The growth of total capital expenditure is shown as the sum of the other two curves. The expenditures on plant and machinery may be approximately estimated in 1958 prices by inspection of Fig. 6(4) and these are given in Table 6(33). The increase in price index for chemical plant is shown in Fig. 6(5) for the period 1950–67. The average increase in price index has been about 2·6% pa. To obtain an estimate of the *current* prices in 1972 and 1977 it would be necessary to assume that the price index increased by about 2·6% pa between 1967 and 1972 (or 1977) and to increase the 1967-priced figures in Table 6(33) accordingly.

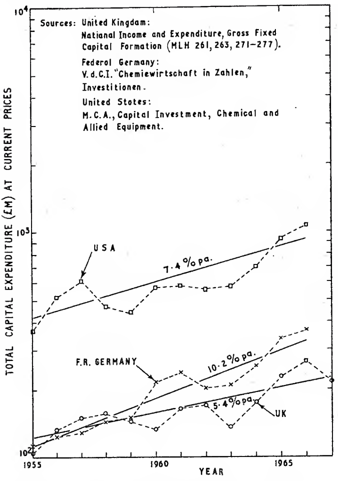


FIG. 6(3). Capital expenditure in chemical industries of UK, USA and Federal Republic of Germany (current prices)

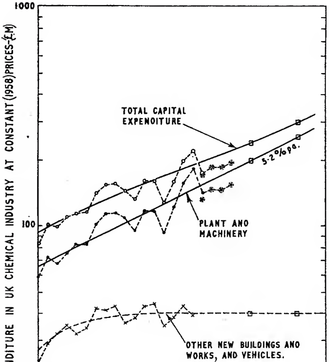


FIG. 6(4). Capital expenditure in UK chemical industry at constant (1958) prices

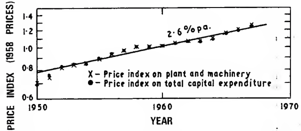


FIG. 6(5). Price index based on 1958 prices for chemical plant for period 1950–67

TABLE 6(33)

Tentative chemical plant expenditure estimates for 1972 and 1977: method A

Estimate		Year (£M)	
		1972	1977
Plant and machinery expenditure	(1958 prices)	200	255
	(1967 prices)	247	315
Other expenditures	(1958 prices)	40	40
	(1967 prices)	45	45
Total capital expenditure	(1967 prices)	292	360

TABLE 6(34)

Vessel contents in plant and machinery expenditures

Year	(a) Plant and machinery expenditure in current prices from Table 6(1)	(b) Vessel content derived from sub-sector analysis Table 6(29) and col. (a)	(c) Vessel content derived from CIA survey Table 6(30) and column (a)
1962	£124M	—	9·2%
1963	100	—	10·2
1964	134	12·3%	14·2
1965	181	9·1	7·4
1966	220	10·7	9·4
1967	173	4·9	9·4
Means 1962–67	£157M	9·3%	9·8%

6.85 It is necessary to estimate the vessel content for 1972 and 1977 from the 'plant and machinery' figures given in Table 6(33). To do this it is first necessary to estimate what proportion vessels are in the total 'plant and machinery' cost. This is done in

Table 6(34), based on the historic series of vessel expenditures for 1962–7 from Table 6(30) and on total plant and machinery expenditures from Table 6(24). The mean values of the vessel content in plant and machinery expenditure are 9·8% and 9·3%. However, in view of the wide range of vessel contents figures obtained according to the types of plant being built and the details of their design from year to year, it is necessary to adopt a wide range of 'vessel contents' in considering total plant cost for the whole industry. The range of 8% to 12% is therefore adopted for the purposes of estimation.

6.86 The forecasts by method A on vessel expenditures for 1972 and 1977 are given in Table 6(35), together with the possible variation arising from uncertainty in the correct 'vessel cost to plant and machinery cost' percentages (a range of 8%–12% is assumed).

TABLE 6(35)

Vessel expenditure forecasts for chemical industry: method A (1967 prices, £M)

Year	Plant and machinery expenditure in 1967 prices (£M)	Vessel expenditure in 1967 prices (£M)
		8%—12%
1972	247	19·7—29·6
1977	315	25·2—37·8

6.87 A basic assumption in the forecast method has been the extrapolation of the trend line in Fig. 6(4) for *all* plant and machinery expenditure, as opposed to deriving trend lines for each of the chemical sub-sectors on an individual basis and then summing the resulting sub-sector estimates. The justification for this procedure is the belief that no substantial changes will take place in the period 1965–75 in the *mean* 'vessel content in *equipment* expenditure' percentages (weighted for the relative proportion of the total chemical industry market held by each chemical sub-sector).

6.88 It was noted in Table 6(28) that the weighted mean 'vessel content in equipment expenditure' percentage for the period 1965–7 is 18·5%. An estimate has been made of the relative proportion of the total chemical industry output held by each chemical sub-sector in 1970, as based on approximate extrapolations (based on Census of Production figures for each sub-sector) to determine the growth rate in each sub-sector. Whilst plastics and organics have much greater growth rates (about 12% pa) than inorganics and fertilisers (about 4% pa), and although these sub-sectors have different 'vessel content in equipment expenditure' percentages, the overall net effect is to produce very little change in the *mean* 'vessel content in equipment expenditure' percentage in 1970, its value then being 18·6%.

6.89 The importance of vessels varies considerably between the different sub-sectors and it was noted above, assuming past trends of development continue, that negligible change would occur in the mean 'vessel content in equipment expenditure' percentage weighted for the whole industry. The figures do suggest, however, that substantial changes may be made in the types of vessels likely to be required as a result of the changing pattern of demand between sub-sectors, the change in scale of production, and changes in technology for both chemical processes and for vessel fabrication and materials.

Forecast demand for vessels in chemical process plant: method B

6.90 For method B forecast the assumption is made that the item 'plant and machinery' expenditure would continue to grow (linearly) by a constant amount each year. This is equivalent to a simple straight-line regression of plant and machinery expenditure versus time in years, and the figures obtained from such a regression based on data for the period 1950–66 are given in Table 6(36).

TABLE 6(36)

Tentative chemical plant expenditure estimates for 1972 and 1977: method B

Estimate	Year (£M)	
	1972	1977
Plant and machinery expenditure (1958 prices)	180	207
(1967 prices)	225	258
Other expenditures (1958 prices)	40	40
(1967 prices)	45	45
Total capital expenditure (1967 prices)	270	303

6.91 The forecasts by method B on vessel expenditures for 1972 and 1977 are given in Table 6(37). As with method A, a range of 'vessel cost to plant and machinery cost' percentages has been used (8%–12% is assumed).

TABLE 6(37)

Vessel expenditure forecasts for chemical industry: method B (1967 prices, £M)

Year	Plant and machinery expenditure in 1967 prices (£M)	Vessel expenditure in 1967 prices (£M)
		8%—12%
1972	225	18·0—27·0
1977	258	20·6—31·0

6.92 It is probable, on balance, that the assumption of a constant growth rate in method A is more likely to occur in the future than the assumption of a constant annual increment in growth as used in method B. For example, if the chemical industry grew by method B (constant annual increment), the annual growth *rates* during the period 1950–77 would be as given in Table 6(38). Since the chemical industry is one of the fastest growing sectors of the UK economy, it is reasonable to assume that the annual growth rate of this industry would not continue to fall as dictated by method B.

TABLE 6(38)

Reduction in annual growth rates of chemical industry by assuming growth by constant annual increment (method B)

Period	Average annual growth rate (% pa)
1950–54	7·7
1960–64	4·5
1970–74	3·1
1976–78	2·6

Demand pattern for vessels in four major sectors in the UK: past and future estimates

6.93 The demand patterns for the major demand sectors, as considered in the present chapter, are given in Table 6(39) and Fig. 6(6). The estimates are very approximate due to the substantial margins of error that arise in methods of ascertaining demand quantitatively. The uncertainty in the demand for vessels is illustrated by the presence of lower and upper estimates in the totals figures, which estimates have been derived by adding the lower and upper estimates for the four demand sectors respectively. The figures given in the table may be interpreted as minimum estimates; for example, a figure of possibly £1–2M should be added to the gas industry demand figures between 1963–8 to allow for LNG storage facilities bought during this period but which have not been included as the information was not available. Similarly, there will no doubt be certain other vessels that have not been included in the present analysis for the four major demand sectors. The magnitude of the total vessel demand quoted in any one year may therefore be less than the actual demand. Thus true demand may be nearer to or greater than the upper estimates in each year.

6.94 Whilst the margins of error are substantial, the demand estimates are reasonable when considered in terms of relative trends. It is apparent that for most of the period 1968–70 demand in the four sectors would fluctuate in the range £40–50M pa, this level of demand largely being maintained by the oil refinery building programme. By 1972 the major oil industry programme would have been completed and demand for vessels in the gas industry would be considerably down. Demand in 1972 would fall to about £30–40M; the high level of demand in 1966 only being re-established (by the long-term growth trends of the electricity and the chemical industries) by 1977 or thereabouts. It must be stressed that a large degree of uncertainty is contained in these forecasts: they should only be used with extreme caution.

6.95 The forecasts, particularly for the second half of the 1970's, are very tentative and are largely based on assuming continuation of past trends in growth. Within this period technological developments could alter the pattern of demand drastically.

6.96 The trend of vessel demand suggests that spare capacity would continue to be a problem in the UK vessel fabrication industry as a whole in the short run. However, the changing pattern of demand could lead to bottlenecks in certain types of fabricating capacity; conclusions of this nature would have to be based on a more detailed analysis of trends in the types of products required in each sector than that made in the present chapter.

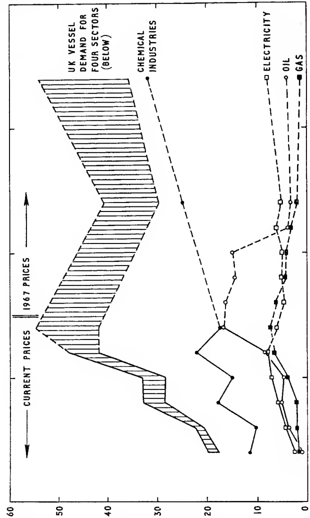


FIG. 6(6). Vessel demand in the UK for four major user sectors

TABLE 6(39)

Approximate annual demand for vessels in major sectors in the UK (£M)

Year	Gas	Electricity	UKAEA	Oil	Chemicals	Totals
Current prices						
1962	1·9+	2·4	0·6	2·4— 3·5	11·4	18·7—19·8
1963	2·2+	4·4	0·2	3·7— 5·3	10·2	20·7—22·3
1964	2·3+	5·8	0·1	4·0— 5·8	16·5—19·0	28·6—32·9
1965	3·9+	7·0	0·1	3·8— 5·5	13·4—16·5	28·2—33·0
1966	6·6+	7·7	0·1	6·9— 9·9	20·6—23·5	41·9—47·8
1967	7·4+	6·1	0·3	14·1—20·2	13·9—20·8	41·8—54·8
1967 *prices*						
1968	6·2	4·8	0·6	13·3—19·1	—	—
1969	4·7	5·4	—	11·8—17·0	—	—
1970	4·6	5·4	—	11·3—16·3	—	—
1971	3·4	6·1	—	2·6— 3·7	—	—
1972	2·1	5·2	—	2·6— 3·7	19·7—29·6	29·6—40·6
⋮						
1977	1–2	6·1— 9·5	—	3·3— 4·7	25·2—37·8	35·6—54·0

Sources: Gas—Table 6(9)
Electricity—Tables 6(18, 19), paragraph 6.53
UKAEA—Table 6(18)
Oil—Table 6(23)
Chemicals—Tables 6(32, 35)

6.97 One of the major conclusions arising from this demand analysis is the increasing dependence of the vessel fabrication industry on the fortunes of the chemical industry. In 1966 the chemical industry represented about 50% of vessel demand in the four sectors, while heavy organic chemicals represented 30% of the chemical industry's demand for vessels. In 1972 it is apparent that the chemical industry would represent about 70% of vessel demand in the four sectors, while it is estimated that the heavy organic subsector would represent about 50% of the chemical industry's demand. Thus heavy organic chemical's importance in vessel demand may increase considerably from 15% in 1966 to about 35% in 1972. It would appear to be in the fabrication industry's best interests to become more process-oriented, or at least to take steps to be informed on likely future developments in the chemical industry, and particularly in heavy organics.

6.98 The estimation of the future demand for vessels in the chemical industry has been more difficult to ascertain than in the other sectors and it is therefore more susceptible to error. In view of the greater uncertainty in estimates of future vessel demand in the chemical industry, and in view of the increasing relative importance with time of this industry as a purchaser of vessels, the total vessel demand estimates are to that extent rendered increasingly uncertain as the time-scale used in the estimation is increased.

CHAPTER 7

UK: balance of supply and demand and data on imports/exports

7.1 It was not possible, during the course of the economic survey, to arrive at a complete 'balance sheet' of the supply and demand aspects for vessels. To compile a supply and demand balance, as an independent check of one against the other, it would be necessary to determine independently: the UK output (of vessels both shop and site-built); the exports from and imports into the UK; and the UK demand.

7.2 On output: as a result of the work reported in Chapter 2 the shop and site-built output in the UK by pressure vessel fabricators in 1966 is known to within reasonably close limits as £73·7M. The supply or output figure of £73·7M relates to vessels produced *only* by pressure vessel fabricators; it does not include heat exchangers and tanks made by non-pressure vessel fabricators.

7.3 On exports/imports: no representative data could be obtained (in 1967) of the levels of UK imports or exports of vessels. Estimates made by the economic survey team led to the suggestion that total exports during 1966 were about £6M to £10M (of which about £1½M were direct exports from the fabricator), while total imports were about £7½M to £11½M implying a negative trade gap of about £1½M. However, since the figure for the trade gap is within the range of estimating errors, too much attention should not be paid towards these estimates.

7.4 On demand: demand in four major vessel user sectors is considered in Chapter 6, and demand for vessels in these sectors totalled £42–48M in 1966. A division of the demand data for vessels into demand data for pressure vessels, heat exchangers and tanks was not undertaken, and it is therefore not possible to attempt a balance of supply with demand in respect of separate data for each of the three main vessel types. Detailed demand analyses for the remaining user sectors (food, brewing etc.) were not attempted, but these would probably prove beneficial in terms of further aids to forecasting if undertaken. Furthermore, little is known about the patterns of demand for replacement vessels and for repair work requiring fabricators' facilities.

7.5 In terms of availability of import/export data, the position has considerably improved since the introduction in January 1968 of new statistical headings in the Customs and Excise Lists. The relevant headings include:

Import headings	*Export headings*	*Items*
71870	E71490	Heat exchangers (e.g. calandrias, condensers, coolers, evaporators, reboilers)
		Process pressure vessels (including autoclaves, distillation columns, fractionating columns, reactor vessels):
71871	E71492	for mineral oil refining,
71872	E71494	other
71873	—	Other

7.6 In respect of direct exports by UK fabricators, data has been collated from the questionnaire returns and this is illustrated in Fig. 7(1). A list of the destination countries is given in Table 7(1).

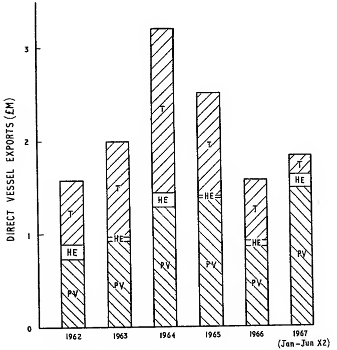


FIG. 7(1). Direct exports of vessels during period 1962–67

Notes: (a) The figures are based on the 17 companies answering the relevant question among the 27 companies in the pressure vessel output groups III, IV and V that returned pilot or revised long questionnaires.

(b) Some companies had no direct exports, while some could not extract figures for direct exports from their records. Equally, some companies may have included some exports made through contractors.

(c) During the period 1962–67: 80% of PV were exported by PV output group V
80% of T were exported by PV output group IV
88% of HE were exported by PV output group III

TABLE 7(1). **List of countries receiving direct vessel exports**

(This list is not representative of the UK direct export trade in vessels, as it is based on only 11 returns for this question)

Country	*Number of mentions*	*Country*	*Number of mentions*
Australia	3	Turkey	1
Holland	3	Canary Islands	1
Iraq	3	Nigeria	1
South Africa	2	Japan	1
Spain	2	Venezuela	1
Yugoslavia	2	Libya	1
Kuwait	2	Hong Kong	1
Iran	2	South America	1
Trinidad	2	West Germany	1
Eire	2	Belgium	1
France	2	Curacao	1
India	2	Sudan	1
Finland	2	Antigua	1
Malta	1	Israel	1
Pakistan	1	Italy	1
Burma	1	Poland	1
Mexico	1		

Tentative balances in 1972 and 1977

7.7 If the overall UK shop-built vessel demands in 1972 and 1977 behave (relative to that in 1966) similarly to the shop and site-built vessel demands in the four major demand sectors as illustrated in Fig. 6(6), then UK shop-built vessel demand in 1972 might be £47M and in 1977 might be £60M (at 1967 prices and on the basis that import and export levels remain unaltered). Unless the level of shop-built vessels exported were to increase during the period 1966–77, the total demand for UK shop-built vessels would at all times during this period probably not exceed the peak vessel demand achieved in 1966. Estimates of likely trends in vessel *demand* for the future enable deductions to be made in respect of the anticipated loading upon the vessel fabrication industry and, in particular, enable trends in *production* levels to be assessed.

7.8 A level of vessel exports at 30% of shop-built production has been achieved by several vessel fabrication industries in overseas countries. This is not an unreasonable level in relation to the performance of mechanical engineering industry in general, and compares with the approximate export level of 15% of UK vessel production in 1966. Furthermore, if the trend towards increasing competitiveness by UK fabricators is maintained, imports to the UK might be held at the 1966 level of 15% of UK shop-built production. An increase in the level of exports to 30% of UK production would then require a nett increase in UK production of 15% which would raise the possible shop-built production in 1972 to £54M and in 1977 to £70M. These figures compare with a level of shop-built production in 1966 of £58M.

7.9 The above very tentative estimates do, however, illustrate the desirability of the UK fabrication industry to increase further its exports both through contractors and by direct sales. This would appear to be necessary if the industry wishes to maintain or increase its annual production during the period 1967–77 over that during 1966. The one way therefore in which UK vessel production could be raised is by increased exports, coupled with maintenance of imports at their present levels.

CHAPTER 8

UK: causes of pressure vessel imports

8.1 It should first of all be stated that it is not possible to give accurately the tonnage and value of pressure vessels imported into the UK during 1962–7. This uncertainty arises from the absence of suitable detail in the import list statistics of the UK and also to the fact that the other sources of information—that of the demand elements of contractors and final users—were in some cases unable or unwilling to provide quantitative information on their sources of supply for pressure vessels.

8.2 Evidence was taken in the course of the survey from both the representatives of the pressure vessel industry in the UK and from the contractors and final users who clearly were the key to imports. From the standpoint of the British pressure vessel industry it is clear that the industry itself was convinced that imports of pressure vessels and shell and tube heat exchangers had been running at the rate of about £20M per year for the latter period of 1965 and the first nine months of 1966. From the standpoint of the findings in this survey it is impossible either to substantiate or refute categorically these statements but it should be pointed out that from interviews with contractors, who procure about 70% of pressure vessels installed in chemical plants in the United Kingdom, and with final users the impression was gained that imports were thought to be at about half this level.

8.3 That there have been imports into the UK for some projects of sizeable value is undisputable and the reasons have been both commercial and technological. These aspects are dealt with in greater detail below.

Technological aspects

8.4 It is considered that the main criteria of choice for most UK contractors when procuring pressure vessels are price and delivery. This does not mean, however, that there is an exclusion of the technological worth of a potential supplier and here the engineering element of the procurement departments of both contractors and final users play a significant role.

8.5 A preliminary choice of likely fabricators is, however, made before price and delivery become the final selection basis. The choice is founded mainly on the technical qualifications of the fabricators with regard to the pressure vessels required. The technical appreciation results usually from either past experience with the fabricator or his known reputation, and this may be connected with visits to the fabricator's shops in order to obtain a better knowledge of the latter's prodnction methods and organisation, with special emphasis upon the quality of work carried out (e.g. welding techniques) and experience in the use of various steels and alloys.

8.6 At this early stage, technical considerations may prevail over the commercial conditions in so far as the pressure vessel required may call upon such sophisticated technological know-how that only a limited number of fabricators can be considered for the pressure vessel in question. The number of cases where pressure vessel imports were the result of technical considerations was very limited, but it does show that British fabricators were not considered (1967) to be technically the strongest candidates to make certain types of vessels, although the size of the British pressure vessel industry is considered by many international contractors to be second in Europe only to that of the Federal Republic of Germany. Some examples of pressure vessels imported are given in Annex E—'UK demand: qualitative review of UK demand sectors'.

Commercial aspects

8.7 Most pressure vessels required do not call upon highly sophisticated fabrication techniques or materials so that the final choice of fabricator is made on price and delivery. Prices and delivery quoted by the foreign suppliers have from time to time proved to be better than those offered by their British counterparts. Furthermore, both contractors and end-users have found that on a number of occasions foreign fabricators have proved to be equally or more reliable than the British fabricators invited to tender for specific jobs. In this context, however, the British pressure vessel industry was very heavily loaded for the latter part of 1965 and for the first three-quarters of 1966 and as a consequence was less keen on price, slower in tendering, longer in delivery estimates and often longer in meeting delivery than many of its Continental competitors, who at that very moment and particularly in Italy were suffering from a marked cut-back in their own domestic demand.

8.8 The British-based contracting industry and a number of the significant final users imported pressure vessels during the peak period of UK demand in 1966 because they were not entirely favourably impressed by the commercial keenness of the British pressure vessel industry at that time. Contractors were also frequently under the exigencies of time penalty clauses and delays in delivery could not be risked.

8.9 Apart from the delivery situation, individual cases were noted *in* **1966** of prices of UK fabricated pressure vessels being 20–30% higher than those imported mainly from Italy but also on occasions from France and the Federal Republic of Germany. This price differential prevailed despite a tariff barrier of 15% (14% for heat exchangers) and transport costs which could be as much as 10% of a CIF price. In the Chapter on 'Foreign Supply—Economic and Technical Factors—Italy'—it can be seen that there were special conditions which allowed the Italian pressure vessel industry to export at very low prices to the UK and there can be little doubt that some Italian pressure vessels have probably been 'dumped' in the United Kingdom. It was stated by some fabricators in Italy that they had been taking export orders at a loss on some occasions, despite the large government export subsidies.

Chauvinism: preference for buying home products

8.10 There is another factor relevant to the import of pressure vessels into the United Kingdom. Contrary to certain commercial prejudices, little evidence was found of chauvinism among British procurers of pressure vessels. From interviews with four or five international contractors in Continental Europe, there was little doubt that the French, German, or Italian final user may make attempts to insist on 'local hardware' for the overall plant contract with a contractor. This chauvinism on the part of Continental European final users tends to be reflected in their national inspection authorities who effectively act, in many cases, as an additional defensive screen against imports of foreign hardware. An impression was formed that appreciable differentials in price and delivery were needed between British and foreign pressure vessel fabricators before orders were placed abroad by UK purchasers. However, there was, at the same time, no question of a 'buy British' policy by the UK purchasers.

8.11 At any given time there will always be at least one overseas country passing through a mild deflationary period and possessing a strong pressure vessel industry. If this pressure vessel industry was also tied closely to steel producers, there would be a strong temptation on the part of steel producers, in order to keep total output high, to sell steel plate fabricated as pressure vessels, even though the profit margin on the vessel may be zero or negative.

8.12 One can understand the position of the chemical contractor and the final user in the United Kingdom who clearly wished to take advantage of the cheapest reliable source of chemical plant available. In the long run, however, the fabrication industry could be harmed and this would not benefit British pressure vessel users. Although it may be tempting to compare the situation in pressure vessels with that of British ship-owners who placed orders abroad in Japanese and Swedish ship-yards, the parallel was not justified. In the pressure vessel industry, there was no evidence that the organisation of French, Italian, German or Swedish fabrication shops offered any production cost advantages over the *better* British shops.

8.13 The consequences of substantial pressure vessel imports on the British pressure vessel industry could be harmful. In the troughs of the demand cycle the pressure vessel industry had to lay off men, particularly skilled platers and welders. When demand picked up again it was very difficult for the fabricator, due to the tightness of the labour market for the skilled welder and plater, to increase rapidly his capacity due to the difficulty of labour recruitment. The fabricator was thus thwarted by the trough and could be unable, due to labour conditions, to expand again when demand increased.

8.14 It is hard to perceive a solution for this vicious cycle because in a sense all West European pressure vessel industries are faced with these same problems. However, in Great Britain's case the pressure vessel industry received less governmental aid in exporting its products in moments of slack home demand than, for example, its Italian counterparts. In addition, through a combination of factors, less protection of the home market was given to British fabricators.

8.15 The 'education' of the demand sector can be achieved partly internally within the contracting and final user industries and this can also be stimulated by the pressure vessel fabricators themselves by the use of: qualified engineering representatives; visits by contractor and final user buyers to the fabrication facilities of a pressure vessel fabricator, etc. However, given an inevitable cyclical demand pattern and the difficulties the heavy fabrication industry faces in increasing capacity rapidly, there can be no real solution to the problem of imports. Moreover, technological change and pure chance (for example, the discovery of natural gas in the North Sea) can completely transform the capital plant requirements of a large industry.

8.16 The following measures are suggested as examples of actions that might help to alleviate the problem:

from fabricators (in conjunction with the trade unions):

more flexibility in shop planning both from the standpoint of equipment and labour (less demarcation to provide flexibility in manpower);

a greater understanding, from market research, of the markets to anticipate demand changes in both volume and type;

greater export activity, with the technological innovation which this implies;

from final users:

a greater understanding of the problems imposed upon the fabricator when he faces rapid fluctuations on his order book;

greater communication between final user and fabricator;

a more orderly scheduling of chemical plant investment. Secrecy must needs shroud the intentions of chemical companies planning to produce chemicals or increase capacity, but speed will be required in the erection of the plant following sanction. Neither of these requirements at company level would be incompatible with a statement of the sum of required fabrication capacity from the relevant sub-sectors of the chemical industry as a whole;

from the chemical contractor:

the buyer should take into account the technical strength of a fabricator and not necessarily limit buying policy to price and delivery;

a buying policy designed to give continuing orders to the most efficient and advanced fabricators in the industry should help them to improve their planning and reduce costs and could be to the advantage both to the fabricators concerned and the contractors themselves;

from the public sector:

the harmful effects of 'STOP : GO' policies on capital plant manufacturers could be alleviated by improvements in the long range planning of capital investment by the public sector.

CHAPTER 9

UK: factors affecting the export of pressure vessels from the UK

9.1 It may be stated with reasonable confidence that less than twenty British pressure vessel fabricators have exported direct—i.e. without selling their pressure vessels to British based contractors who would then export in the form of turnkey plants—in the last few years, out of a total of more than 250 companies who had produced pressure vessels.

9.2 The reasons for the small quantity of direct exports were not hard to seek and may be summarised as follows:

there was a trend, which would probably increase, for all countries to insist on the maximum of locally built hardware for any chemical plant put down in their country. As pressure vessels were generally not of a very high degree of technological input, most nations with some industrial development were able to manufacture uncomplicated mild steel vessels;

the further reasons concerning the situation prevailing in a number of British pressure vessel fabricators:

only a few had international operations and many were not 'export minded';

many had not the resources individually to mount the exploration and selling effort needed;

most had not joined together with other British fabricators to form export companies (to share costs) for attacking overseas markets;

British pressure vessel prices had not been entirely competitive in as many instances as were desirable due to steel pricing policy, productivity and transport costs;

very few were in contact with the overseas contractors who, as in the United Kingdom, were important intermediary procurers of pressure vessels.

9.3 The modest size of direct exports need not matter so much provided the contractor exports were large. However, the British based contractor, who was not usually tied to any hardware facility and who wished to compete internationally, was obviously anxious to get in a tender as low as possible and, therefore, placed his pressure vessel order with the lowest acceptable pressure vessel quotation. He had some restraint in ECGD with its insistence on the highest possible portion of British hardware, but where the contractor could show that the British fabricating industry could not meet technological requirements, or that the use of British hardware would mean the loss of a complete contract, the necessity to use British hardware could be waived. Normally up to 30% foreign content was agreed if the contractor believed it might lose the entire contract.

9.4 In this context it should be noted that a number of examples were given by British contractors of the very low prices during 1966 from foreign pressure vessel fabricators as well as good delivery times. This was possibly understandable for plants to be erected in the EEC, but for 'neutral' territories (such as Spain, Finland and Africa) foreign quotations had been 15–30% lower than those from the UK *in* 1966. An increase in pressure vessel exports via contractors would arise when British pressure vessel fabricators were in a position, as a technically advanced and well-organised industry, to make an adequate contribution to the export selling of the British contractors. The view of the latter in 1967 was that British fabricators should make substantially more effort in this direction. However, the UK pressure vessel industry was more competitive on price in 1968 following a reduction in home UK demand.

9.5 A number of contractors and fabricators considered the British inland transport system contributed to higher prices, and the position may be worsened by the new transport regulations. Others stated that British ports—for reasons not readily apparent—seemed to represent considerable bottlenecks for *exporting* large and heavy vessels but not for their *import*.

9.6 The British chemical contracting industry has had notable success in overseas markets. There were further considerable areas of the world in which the industry had not yet been active such as, for example, Latin America and the United States. In the context of exports there should be more contact between British based contractors and the fabricators. Both ultimately had the same market interest being dependent upon the locating and obtaining of contracts for construction of chemical and allied industrial plants. Contractors were asked during the survey whether they would be prepared to carry out joint market research with fabricators; in nearly every case no receptive comment was received.

9.7 During the survey the various associations were consulted which group the suppliers of equipment to the oil industry, gas industry and chemical industry, together with, of course, the specialised association which groups most of the significant pressure vessel fabricators. Meetings were also arranged with the British National Export Council and two organisations which specialised in the organisation of export credit for British capital plant.

9.8 There was a certain fragmentation and overlapping in the size and role of these associations and their work was insufficiently co-ordinated. Each was individually doing an efficient job but their overall utility could be increased if there were more co-ordination between the various organisations. The fragmentation also implied that there was no single organisation large enough to carry out the market intelligence function on the same scale as, for example, the VDMA and the Fachverband Dampfkessel-Behälter und Rohrleitungsbau in the Federal Republic of Germany.

9.9 The following paragraphs provide a few suggestions for possible action.

9.10 *First*, a list is given in Annex G of significant chemical contractors in the Western World and alongside each is indicated the possession or otherwise of heavy fabrication facilities. The first approach for any fabricator wishing to export to any of the listed countries should be to make known his competence to the contractors in the appropriate country.

9.11 *Secondly*, to overcome the limiting size and resources of many fabricators, consideration might be given to the formation of an active Export Council; possibly within the Tank and Industrial Plant Association, which could act as a stimulant to the formation of an export company for a group of members, with salesmen, overseas offices and/or agents. This policy could complement the Market Information Service. Alternatively, an Export Council for Process Plant might be created to deal with all the equipment required to construct process plant. Each product sector (pressure vessels, pumps, pipes etc.) could be dealt with separately at the detailed level but the advantages of scale of operation and co-ordination would not be lost.

9.12 *Thirdly*, although no survey has been done in the United Kingdom at governmental level into the relationship between added value and export performance for the mechanical industries, the standard mild steel pressure vessel was not a product of high added value and it incurred high transport charges in relation to its value. Better organisation for exporting should be complemented by the continued strive for innovation whether it be in design or in the use of newer materials for pressure vessels. There are ample technological resources in the United Kingdom and all the necessary know-how with regard to stainless steel, clad steels and the newer metals such as titanium and zirconium, upon which to base a substantial export-orientated section of the British pressure vessel industry. This could make a substantial difference to the work load of companies that had the desire to proceed along these lines.

9.13 *Fourthly*, an essential change must be one of attitude. Exporting is complicated, but the managements of many pressure vessel fabricators were not export-orientated, and a major change of attitude would be needed if there were to be any shift in the considerable dependence of British fabricators on the fluctuating demands of the British home market. This change of attitude towards exports should go hand in hand with engineering innovation which should be combined with development of: work programming, shop control, proper sequencing of material procurement, and flexibility in labour.

9.14 *Fifthly*, there was no doubt about the first class service of the ECGD. The ECGD offered facilities comparable with those prevailing in, for example, France and the Federal Republic of Germany. Export credit facilities in London were good, and there was a wide range of specialist organisations for the export of capital equipment. Whilst the general know-how of the City of London backed by ECGD guarantees could make it possible for British exporters of capital plant to offer terms comparable with those of other major capital plant exporting countries, it is felt that the creation of a large-scale UK Export Credit Bank could rapidly help the UK as a leader in the export of pressure vessels.

CHAPTER 10

Foreign supply: output

Output: France

10.1 No detailed statistics are available on pressure vessel output in France. No separate figures for pressure vessels were found in published sources, and a specific enquiry to INSEE—Institut National de Statistiques et des Etudes Economiques (France's central statistical office) only yielded some figures for 1962. The Syndicat National de la Chaudronnerie, de la Tôlerie et de la Tuyauterie Industrielle—the French equivalent of TIPA—itself either did not have, or did not wish to disclose, this data.

10.2 The published data on boiler and pipework is given in Table 10(1).

TABLE 10(1)

Heavy boilerwork output: France

Product	*Unit*	1961	1962	1963	1964	1965	1966
Boilers	Tons	29,200	26,100	19,900	26,400	19,500	38,700
Material for the petroleum industry	Tons	103,900	96,400	100,300	124,300	116,200	125,000
Other materials	Tons	268,500	280,800	286,700	285,000	266,000	314,000
TOTAL TONNAGE	Tons	401,600	403,300	406,900	435,700	401,700	477,700
TOTAL VALUE	FF.m.	1,658	1,772	2,044	2,070	2,130	2,270

Source: Ministry of Industry, Paris

10.3 The above data concerns the output of 900 companies, employing about 40,000 workers. The Syndicat National also gave a figure of 450,000 tons as total output for 1966, which agrees with the Ministry of Industry's statistics in the table.

10.4 Heat exchangers were exported into many different countries, mainly in Western Europe, while about 60% of imported heat exchangers were bought in the Federal Republic of Germany. An indication of the output and trade of heat exchangers in 1966 was also obtained from the Syndicat National:

production : FF 130 to 150 million
export : FF 71 million
import : FF 47 million

10.5 According to the Syndicat, the industry bought 255,000 tons of steel plate from the French steel industry in thicknesses of more than 3 mm, and 25,000 tons of alloy steel, i.e. stainless and refractory steels.

10.6 France's total pressure vessel output in 1966 was estimated at about £40M, according to a consensus of informed opinion by a number of fabricators.

Output: Federal Republic of Germany

10.7 Apart from process heat exchangers, no available statistics were found on output of individual products either in tonnage or in value. Published statistics provided only overall figures, and the data of Table 10(2) were obtained by a specific enquiry to the Federal Republic of Germany's Central Statistical Office in Wiesbaden. Only the trade associations could provide more details but these were classified as confidential to members.

TABLE 10(2)

Heavy boilerwork production: Federal Republic of Germany

Product / Year	1960	1961	1962	1963	1964	1965	1966
PRODUCTION IN '000 TONS							
Boilers and accessories	98·6	98·2	107·0	101·6	107·6	131·8	131·3
Heat exchangers for superheating	4·5	5·3	6·1	8·1	5·7	6·7	7·0
Process heat exchangers	4·4	5.2	6·0	7·3	7·8	9·4	9·7
Explosion-proof tanks and accessories, evaporators and vacuum apparatuses	10·1	10·6	12·4	11·8	11·5	12·9	9·5
Various pressure vessels and tanks for the chemical and allied industries	202·7	205·3	203·8	191·1	179·3	206·4	210·6
Total tonnage in '000 tons	320·3	324·6	335·3	319·9	311·9	367·2	358·1
PRODUCTION IN £M							
Boilers and accessories	30·1	34·3	37·7	37·6	40·2	51·0	48·7
Heat exchangers for superheating	1·6	2·0	2·5	3·4	2·6	3·1	3·27
Process heat exchangers	2·0	2·4	2·8	3·3	4·5	4·9	5·7
Explosion-proof tanks and accessories, evaporators and vacuum apparatuses	2·9	3·4	3·9	3·8	4·0	4·8	4·9
Various pressure vessels and tanks for the chemical and allied industries	33·4	35·4	35·5	33·2	33·1	39·8	42·4
Total value in £M	70·0	77·5	82·7	81·3	84·4	103·6	104·9

Source: Statistische Bundesamt. Note that 'heavy boilerwork production' on the continent means 'heavy fabrication production' and includes not only production of boilers but their accessories as well as tanks, heat exchangers, pressure vessels, etc.

10.8 The vessel content of the total output in the above table was estimated by a brief engineering appraisal of the German chemical engineering industry, which suggested the following:

Boilers, about 65 to 70% of the tonnage, and 50 to 60% of the value indicated;

Heat exchangers for superheating, as part of major boiler installations, the same as for boilers;

Process heat exchangers, almost 100%;

Explosion-proof tanks, etc., similar to pressure vessels;

Various pressure vessels and tanks, 50 to 60% of the tonnage and 70 to 75% of the value indicated.

10.9 These percentages permitted reasonable estimation of vessel content in heavy boilerwork production. Combined with foreign trade statistics, the export position was also obtained as shown in Table 10(3).

TABLE 10(3)

Imports, exports and balance of foreign trade in heavy boilerwork

	1964		1965		1966	
	tons	£'000	tons	£'000	tons	£'000
IMPORTS						
Tanks more than 300 l	5,600	1,180	8,700	1,460	7,800	1,290
Pressure vessels for liquid gases	2,100	436	3,000	693	4,500	982
Boilers	1,200	584	1,100	527	800	264
Total imports	8,900	2,200	12,800	2,680	13,100	2,536
EXPORTS						
Tanks more than 300 l	24,500	5,180	23,600	4,940	23,900	5,060
Pressure vessels for liquid gases	20,900	4,340	19,800	4,430	20,200	4,830
Boilers	34,800	12,580	37,700	14,870	37,400	15,690
Total exports	80,200	22,100	81,100	24,240	81,500	25,580
(Exports – Imports)						
net trade balance	71,300	19,900	68,300	21,560	68,400	23,044

Source: National Foreign Trade Statistics, Federal Republic of Germany

10.10 The above table contains what appears in the Federal Republic of Germany's Foreign trade statistics as imports and exports for vessels. There may be some exports and imports 'hidden' in other headings of the country's foreign trade statistics. The method used for determining the vessel content of heavy boilerwork exports is the same as that used for the Federal Republic of Germany's pressure vessel production, i.e. a (vessel/boilerwork) ratio, expressed as a percentage, was derived from the estimates of the pressure vessel content in the various process plant listed under Table 10(2). A weighted average figure was obtained for application to the totalled 'tonnage' and 'value' export data. The results are shown in Table 10(4).

TABLE 10(4)

The export factor in the Federal Republic of Germany's vessel output

	$\left(\frac{\text{Vessel}}{\text{Boilerwork}}\right)\%$		1964		1966	
Product	On tonnage (%)	On value (%)	Tonnage (tons)	Value (£M)	Tonnage (tons)	Value (£M)
Boilers	66%	55%	71,000	22·2	86,000	26·8
Heat exchangers for superheating	66%	55%	3,800	1·4	4,600	1·8
Process heat exchangers	100%	100%	7,800	4·5	9,700	5·7
Pressure vessels and tanks	55%	75%	105,000	27·8	121,000	35·4
Total production			187,600	55·9	221,300	69·7
Exports	65%	66%	52,100	14·6	53,000	16·9
EXPORTS/TOTAL PRODUCTION %			27·8	26·2	24·0	24·3

10.11 Table 10(4) shows that exports as a percentage of total production, calculated on a value basis, has fallen slightly from 26% in 1964 to 24% in 1966. Furthermore, this was accompanied by a greater reduction in the percentage tonnage exported, implying that during the period 1964–6 there was a trend towards the export of vessels of higher value per ton. The 24% exported by the boilerwork industry compares slightly unfavourably with the performance of 25–27% of the Federal Republic of Germany's capital goods industry as a whole.

Output: Italy

10.12 Italian production of boilerwork in 1966 was 150,000 tons, of which it is estimated 60,000 tons related to vessels. In cash terms, of the 1966 boilerwork production of £34M, about £18M related to vessels.

10.13 Table 10(5) shows figures from 1963, with estimates up to 1970, for production of all general boilerwork: the percentage of vessels is not indicated by the figures, but these do nevertheless give a general impression of trends. (An even clearer indication of trends is shown by the curves in Fig. 12(1).) The source for all these figures, including imports and exports, were the annual reports of ANIMA (Italian Association of Miscellaneous Mechanical Manufacturing Industry) as estimated, collated and published by CONFINDUSTRIA, and are *not* official statistics. All the figures, including imports and exports, relate to the boilerwork as defined at the bottom of the table.

10.14 Export of boilerwork *in general* during 1966 amounted to £6M or 17% of total production of £34M. The proportion of *vessel* production exported was probably higher than the general figure of 17% as it is a more specialised product (higher value per ton). As the exact figures for export of vessels (as opposed to boilerwork in general) were not known, the minimum export figure was obtained by assuming that the same percentage (17%) of vessel production was exported as for boilerwork production; this gave £3M. The maximum export figure was obtained by assuming that the total boilerwork exports in 1966 of £6M were all vessels. This gave a percentage of 32% as the upper limit for exports of vessels during 1966. The actual level of vessel exports in 1966 was probably mid-way between the upper and lower limits, i.e. at 25 ± 7%.

TABLE 10(5)

Production of boilerwork** in Italy

	1962	1963	1964	1965	1966	1967	1968*	1969*	1970*
Capacity (billion lire)	—	84	88	90	95	120	120	125	125
Capacity – utilisation (%)	95	95	78	61	63	65	72	70	69
Production (tons – '000)	205	223	166	130	150	—	—	—	—
(billion lire)	73·8	79·6	68·8	55	60	72	86	88	86
(£M)	—	45	39	31	34	41	49	50	49
Employed ('000)	—	—	—	—	9	9·6	10·2	10·3	10·4
Fixed investments (billion lire)	—	—	—	—	2	6·2	7·3	7·5	5·3
of which: renewal	—	—	—	—	0·8	1·4	1·6	1·7	1·3
new net	—	—	—	—	1·2	4·8	5·7	5·7	4·0
Geographical distribution of production:									
Centre+North (%)	—	—	—	—	95	95	92	90	90
South +Islands (%)	—	—	—	—	5	5	8	10	10
Imports (billion lire)	—	—	—	4·6	2·4	—	—	—	—
Exports (billion lire)	—	—	—	7·1	10·0	—	—	—	—

* **Estimate**

** Includes: pressure vessels, reservoirs, cisterns, tubes, tanks and other similar containers having a capacity of over 500 litres, made of cast iron, iron or steel (rough surface, polished, or however finished, also by cladding or coating by other products);
metal construction in iron or steel, parts and fabricated elements (not including general steel structural work, ie 'carpenteria' which comes under a separate heading); distillation columns, heat exchangers, etc. are included in this heading (machines and equipment for the chemical industry, ie lighter manufactures, come under a separate statistical heading);
steam boilers (heavy shell internally fired, flue tube, multitube or forced circulation); steam boiler auxiliary equipment; steam boiler parts and components.

Source: CONFINDUSTRIA—Approximation: 1 billion lire=£0·6M

Output: Sweden

10.15 The only statistics available on vessel output concern the production of boilers which developed between 1961 and 1965, and these are given in Table 10(6). The production of vessels, ie the vessel content of heavy boilerwork output, has been estimated at £4M in 1966.

TABLE 10(6)

Boiler production: Sweden

Year	1961	1962	1963	1964	1965
Production of boilers	5,900	6,880	7,320	7,070	7,470

Source: Swedish Central Statistical Office

10.16 Foreign trade statistics are, however, available for boilers and pressure vessels and these are given in Table 10(7).

TABLE 10(7)

Imports and exports of boilers and pressure vessels: Sweden

(£'000)

	1962	1963	1964	1965	1966
IMPORTS					
Boilers	910	680	550	630	360
Pressure vessels	180	290	410	470	53
EXPORTS					
Boilers	1,420	1,050	720	620	570
Pressure vessels	47	146	95	152	36

Source: National Foreign Trade Statistics

10.17 The net exports for boilers as a percentage of total boiler production was about 10% in 1962, but in 1965 Sweden became a net importer of boilers. In comparing the value of pressure vessel exports to the estimated turnover, the export factor for pressure vessels (not taking account of imports) appeared to have been significantly lower than 10%. Imports of pressure vessels have however been considerably higher than exports throughout the period in question, and Sweden is therefore a net importer of pressure vessels.

Output: Japan

10.18 Insufficient data on output could be found in publications available in Europe, and no information could be obtained from Japanese professional sources. The following data in Table 10(8) was obtained from the Ministry of International Trade and Industry, Tokyo.

10.19 Total output in value has been fairly stable. The values of production of the various types of pressure vessels in the table compared to their respective numbers built would imply a decrease in average price per vessel, although such a statement must be considered with care because information on the individual size and quality of the vessels produced was not available.

TABLE 10(8)

Japanese vessel output 1964–1966

(Values in £, calculated at the conversion of £1 per Y 1,000)

Product		1964	1965	1966
Reaction vessels	£	9,951,058	9,949,644	11,201,361
	No.	3,509	5,259	7,769
Evaporators and crystallizers	£	2,066,922	3,247,609	2,585,544
	No.	857	880	887
Distillers plant	£	5,067,258	5,597,639	5,714,809
	No.	396	621	532
Extractors	£	1,968,623	1,874,875	1,419,369
	No.	310	331	239
Tanks for chemical equipment	£	14,865,657	13,727,512	13,922,274
	No.	15,684	19,094	18,487
Heat exchangers (shell and tube)	£	10,638,224	11,040,711	10,818,365
	No.	10,554	9,571	10,615
TOTAL VALUE	£	44,899,884	45,437,990	45,661,722

Source: Ministry of International Trade and Industry

TABLE 10(9)

The production of boilers in Japan

(Finished goods for general use)

Year	Quantity (No.)	Capacity (t/h)	Value (£M)
1961	4,835	14,078	32·44
1962	5,299	16,811	36·37
1963	6,404	21,615	52·13
1964	8,249	21,211	41·25
1965	7,502	21,779	42·22
1966	8,585	24,470	43·45

Source: MITI

10.20 It is estimated that between 20% and 50% of the output value of boilers given in Table 10(9) corresponds to vessel production. The value of the country's total vessel production in 1966 may thus be considered as amounting to between £54M and £67M. These production statistics may however be incomplete, and this becomes evident when comparing these figures with exports of heat exchangers as given in Table 10(10). According to these, from a production of £11M (see Table 10(8)) more than £16M of heat exchangers appear to have been exported in 1966. This inconsistency was probably due to the fact that the heat exchangers listed under Table 10(8) were the heavier tube and shell type, whereas in Table 10(10) process heat exchangers and parts probably concerned complete (and components for *all* types of) heat exchangers. However, the export figures—although the products which they contain may not be completely relevant to this study—do show the strong export trade of Japan.

TABLE 10(10)
Tank and heat exchanger exports by Japan

Product		1962	1963	1964	1965	1966
Tanks and similar containers in iron and steel	Tons	2,650	8,190	17,900	56,930	83,800
	£'000	420	1,200	1,320	2,040	3,430
Process heat exchangers and parts	Tons	1,620	3,960	5,040	14,070	32,920
	£'000	793	1,520	2,985	7,890	16,540

Source: National Foreign Trade Statistics

10.21 According to Japanese foreign trade statistics and to the Ministry of International Trade and Industry, imports of pressure vessels were negligible. There may have been, however, some significant 'hidden' imports of pressure vessels, ie as part of imported plant and machinery installed in turnkey plants.

10.22 Shipbuilders play a prominent role in the manufacture and export of heavy machinery and plants and appliances. Overseas orders for chemical plants received by the Japanese industry during the period April, 1964–March 1965 totalled £670M, of which the share of the country's eight leading shipbuilders amounted to 41%. Orders for chemical equipment (oil tanks, pressure vessels, towers and columns) in the same period totalled £14M of which the eight shipbuilders received 40%, ie £5·6M.

CHAPTER 11

Foreign supply: structure

Outline of French pressure vessel industry

11.1 France's boilerwork industry as a whole consists of 704 companies, and its structure is illustrated in Table 11(1). The main conclusions that can be drawn from the table are the following:

> there are a great number of small companies: 74% of the total number of companies have less than 50 employees, occupy 26% of the industry's manpower, and produced 29% of the industry's turnover in 1966;
>
> 87% of companies have less than 100 employees (45% of total) and produced 48% of total turnover;
>
> only 38 companies (5·4%) have more than 200 employees (40%) with 34·8% of the industry's total turnover;
>
> there is a relationship between the size of a company and its turnover per employee; the ratio (turnover: employee) is the highest with small companies. No explanation is attempted here as to why the TO (turnover) per employee should fall substantially as the size of the individual company increased. This result would, on the face of it, appear to counter arguments that large industrial companies had a higher productivity than small companies.

11.2 According to CPCT there are 181 companies employing 17,800 people classified as specialising in welded construction. No detailed data was available on the size of companies in this sector. Moreover, it appeared that a number of large companies fabricating a significant part of the country's pressure vessel output, were not amongst the 181 specialised boilerwork producers. There were also a few small and medium-size companies not included in these 181 companies.

11.3 The main geographical concentration is in the Paris area, while other important concentrations are in the region of the Massif Central and Lyons, and in the North and North-East (where iron and steel and other heavy industries were situated). Three important fabricators are near maritime ports: Chantiers de l'Atlantique at St. Nazaire; Brissonneau et Lotz (the locomotive manufacturer) at Nantes; and Constructions Métalliques de Provence with fabrication units at Arles near the Mediterranean, and at Dunkirk.

11.4 The French pressure vessel industry can therefore be seen to be characterised by a large number of small companies with only a few of the larger of international significance. About ten to fifteen fabricators are responsible for more than 50% of output. Of these large companies, about one-third are linked to major steel groups. The others are mainly members of major equipment groups, some of whom have chemical engineering contracting associates. One company only stands out due to the strength of its direct exports.

TABLE 11(I)

Structure of French boilerwork industry[4]

Companies' No. of employees	No. of companies	%	T.O. France	%	Exports		Total T.O.[1]	%	T.O. per employee[2]
					T.O.[1]	%			
up to 10	150	21·3	50 343	3·0	1 315	1·0	51 658	2·9	54 490
11 to 20	139	19·7	114 222	6·8	5 273	4·2	119 495	6·6	57 532
21 to 50	230	32·7	339 762	20·3	15 678	12·4	355 440	19·8	47 405
51 to 100	97	13·8	320 161	19·2	16 339	12·9	336 500	18·7	49 347
101 to 200	50	7·1	296 523	17·8	13 038	10·3	309 561	17·2	44 676
201 to 500	27	3·8	297 592	17·8	66 185	52·3	363 777	20·2	44 861
+500	11	1·6	252 962	15·1	8 821	7·0	261 783	14·6	32 383
TOTAL	704	100	1 671 565	100	126 649	100	1 798 214	100	44 440[3]

Notes: TO = turnover
(1) = thousands of francs
(2) = francs
(3) = average for whole industry
(4) = 'Boilerwork' here means 'heavy fabrication industry'

Source: Centre de Productivité de la Chaudronnerie et de la Tôlerie—CPCT—Paris 1967

11.5 French pressure vessel fabricators may be divided into three groups according to their output of pressure vessels:

Large Output. The ten to fifteen companies in this category are responsible for the bulk of French pressure vessel production. Although no precise figure can be given for their share in French pressure vessel output, their overall importance may be rated as more than half of the industry's, since they are representative of the country's activities in the pressure vessel field, especially concerning international competition in France and abroad. A selection of companies in this group are:

Constructions Metalliques de Provence;
Schneider—Creusot;
Société Franco—Belge SA;
Vallourec;
Compagnie des Ateliers et Forges de la Loire;
Brissonneau et Lotz;
Lorraine—Escaut;
Chantiers de l'Atlantique;
S.F. de C. Babcock et Wilcox;
Babcock—Atlantique;
Stein et Roubaix.

Medium Output. The companies in this group are of secondary importance in French pressure vessel production, although it does altogether produce about one-third of the total French output.

Small Output. Among other companies, either of smaller size or with less interest in pressure vessel fabrication, there are about 40 companies claiming to be active in the pressure vessel field—according to their appearance in the yearbook of the French petroleum, natural gas and petrochemical industry (plant and equipment) manufacturers.

11.6 Brief notes on a selection of large and medium size French pressure vessel fabricators are given in Annex H.

Outline of the Federal Republic of Germany pressure vessel industry

11.7 No satisfactory definition was found for the German pressure vessel industry either in terms of products (statistics) or in terms of companies. The least difficult group to define in the pressure vessel industry was the boilermakers, especially the fabricators of smaller boilers. The presence of association membership could help to determine whether a given company's main specialisation was in conformity with the association's profile, but many companies belong at the same time to several associations. Apart from two other specialised associations, most pressure vessel fabricators belong to the VDMA, grouping all the mechanical industries in Germany, the different sections of which embrace also practically all the metallurgical companies. Most of the 22,000 companies of the capital goods industry are members of VDMA through one or several of its Fachgemeinschaften. Most boilerwork makers are, moreover, members of the boilermakers' and/or vesselmakers' associations.

11.8 Data on the Federal Republic of Germany's capital goods and boilerwork industry is given in Table 11(2), and is drawn from the VDMA industrial census carried out in the Federal Republic of Germany in 1963, and gives data for 1962.

TABLE 11(2)

Data on the Federal Republic of Germany's capital goods and boilerwork industry in 1962

	All companies			*of which* companies with more than 10 employees	
	No. of companies	Total No. of employees	Total turnover (£M)	No. of companies	Share (%) in total turnover
Capital goods industry, total	21,908	3,531,000	10,477	13,833	99·3
of which					
Boiler, vessel and pipework industry	381	68,200	193	284	99·2

Source: Statistisches Bundesamt. Zensus im Produzierenden Gewerbe, 1962

11.9 As to the geographical location of the industry, small and medium-size companies are spread all over the country. The large companies are, however, mainly located in the Ruhr-Rhine area (with the major exception of MAN, Augsburg) the greatest concentration being in the heart of the Ruhr itself. A considerable part of domestic demand for pressure vessels is concentrated in the same region, as well as the raw material sources. The advantageous transport costs and facilities offered (e.g. communication, trained manpower, infra-structure) in an area with such highly concentrated industrial activities, more than offset the effects of higher wages and salaries, scarcity of land, etc. The advantage of installing pressure vessel shops on the Rhine is obvious in view of the water transportation facilities for exporting pressure vessels (e.g. Klöckner-Humboldt-Deutz and Pintsch-Bamag).

11.10 There is a wide variety of large, medium-size and small companies, although the more important to be considered are the large companies, for they are all active on international pressure vessel markets as well as on the German market, their competitive position being usually enhanced by horizontal integration as well as, in most cases, an important vertical integration. Further comments on large integrated companies are given below.

11.11 The large integrated companies of the Federal Republic of Germany represent the bulk of the industry, and although no data are available as to their relative share in the Federal Republic of Germany's production of pressure vessels, their policies probably determine the country's market in pressure vessels. A number of large companies having comparable structures are financially linked together in horizontal integration. This *financial* integration is a complex one: while paralleling the industrial organisation of the companies concerned, it extends their market power in controlling some sectors of final demand for pressure vessels. Subtle financial links also exist between some of these large companies themselves through their respective groups. Finally, they often have, at the groups' level, wholly-owned subsidiary export companies but tbese do not, however, affect significantly the usual demand circuit for exported pressure vessels, i.e. the role of contractors.

11.12 The vertical integration is *industrial* and is more important than the horizontal; it consists of heavy mechanical construction and machine building linked to the steel industry with, occasionally, contractors interests as well. The disposal of captive raw material—steel for pressure vessel fabrication—stemming from vertical integration may be an advantage or a liability. When order books are heavy, the benefit is considerable: shorter delivery and stable prices within the group. In 1967 it was considered a disadvantage: there was pressure to use steel plates produced within individual groups without the usual bargaining possibilities offered by a buyer's market.

11.13 Brief notes on a selection of German fabricators are given in Annex H.

Outline of Italian pressure vessel industry

11.14 The bulk of Italian pressure vessel production is the output of about a dozen small to medium size companies (300 to 600 employees), some of the more important of which are privately owned and directly run by the owners. There are a further number of small companies reported by many to be capable and efficient, which have created substantial business in the recent years due to their low prices and eagerness to meet customers' requirements.

11.15 There is no official classification of companies in Italy (e.g. Lloyds class) but the *more prominent companies* most usually called on by international clients for more exacting work, can be grouped as:

two companies with a total turnover of about £8M/year, reported as more specialised in high quality steels, alloys, etc., and intricate design of vessels, manufacturing typical components of chemical and petroleum plants, etc.:

FBM, Milan;
Bonaldi, Crema (Cremona);

four companies with a total turnover of about £12M/year, known more for their large and heavy carbon steel vessels:

Nuovo Pignone, Massa;
Bosco, Terni;
Belleli, Mantova;
Sartori, Mestre (Venezia);

a group noted for their manufacture of heavy forgings, dished ends, etc., which they supply to other fabricators (both are also steel manufacturers):

ATB, Brescia;
Terni, Terni;

companies highly specialised in special materials (stainless, titanium, special alloys):

Siai-Lerici, Cormano (Milan);
Zanon, Schio (Vicenza);

important mechanical engineering companies, considered as time-to-time suppliers in the pressure vessel field:

Ansaldo Meccanico-Nucleare, Genova;
Breda Termomeccanica e Locomotive, Milan;
Tosi, Legnano;
others (e.g. Badoni, CMF, BPD, etc.)

the smaller fabricators, including:

Bergum, Chignolo d'Isolo (Bergamo);
Ceccoli, Bologna;
Del Monego, Legnano (Milan);
Fergal, Gallarate (Varese);
Gavazza, Bologna;
ICM, Marghera (Venice);
OCM, Padova.

11.16 The following miscellaneous comments are relevant for the more prominent companies:

all major Italian fabricators are located in the industrial north but away from the high-cost-of-labour Milan, with the exception of:

FBM, with present works in Milan but soon moving to new premises near Bergamo;

Siai-Lerici, Cormano (within the Greater Milan Area) specialising exclusively in high value stainless steel, etc;

Bosco and Terni, located at Terni (towards Rome) for historical reasons;

from the point of view of ease of transport, only Nuovo Pignone and Sartori are located conveniently enough to the sea and this shows up in the size of their typical production;

there is only one case, Nuovo Pignone, of a fabricator linked with a contractor (SNAM—both are part of the ENI Group, the State organisation for petroleum and allied production) but the link is not a 'closed' one, in the sense that SNAM can procure elsewhere;

two companies of the IRI-Finsider Group, ATB and Terni, produce steel and consequently a great amount of their work is in the supply of forgings and parts (thick plate rolled sections, dished ends, etc.) to their fabricators. Another company of the Group, Dalmine, is an important supplier of thick-walled and normal tubing, and makes gas containers up to 9 meters diameter;

three large mechanical engineering companies (4,000–5,000 employees each: Ansaldo MN, Breda TL, and Tosi) in the fields connected with pressure vessels are best known for boilers, but above all Ansaldo and Breda (both State owned) have supplied various chemical plants and components both to Italian and foreign clients (e.g. Ansaldo's co-operation with Montecatini engineering design for a number of chemical plants in Russia);

two companies are reported to be linked with foreign steel suppliers: Siai-Lerici with Avesta and Bosco with Thyssen;

FBM, Belleli, Bonaldi and Bosco are reported to be equipped with very modern machines, e.g. automatic welding, numerically controlled machine tools, and complex testing equipment;

all the major fabricators have engineering design departments, e.g. FBM are reported to have about 25 persons, the others less except Nuovo Pignone whose design department is larger.

11.17 Brief notes on a selection of Italian pressure vessel fabricators are given in Annex H. Also given in the Annex are notes on the very considerable influence of the State organised industries in Italy, particularly the aspects of strong horizontal and vertical integration within the various State Groups: ENI, IRI and EFIM.

Outline of Swedish pressure vessel industry

11.18 There are about 50 companies active in pressure vessel fabrication in Sweden, of which about 30 of these may be considered specialists, the remainder mainly concentrating on boilers (6 are specialists in boiler building) and/or storage tanks. The total number of employees in the 30 companies fabricating pressure vessels is estimated at 15,000, but this covers their whole range of activities and not only pressure vessel fabrication. The most important fabricator is Uddeholms, while another important fabricator is Avesta Jernverks (a member of the Axel Johnson Group of Sweden, which also includes two other fabricators: AB Hedemora Verkstäder and AB Svenska Maskinverken). Other significant fabricators are the following:

AB A. Ekstroms Maskinaffär
AB Evaporator
AB Götaverken
AB Rosenblads Patenter
Stal-Laval Turbin AB
AB Thermia-Verken

11.19 There are 15 to 20 other fabricators of pressure vessels, but either they are too small to be considered, or significant companies having only a small activity in the pressure vessel field.

11.20 The Swedish pressure vessel industry thus consists mainly of a very few highly specialised companies, such as Uddeholms. Pressure vessel fabrication is not significant in many other of the large, well established mechanical companies. The main reason for this may be due to the late development of the chemical industry in Sweden.

11.21 Brief notes on Swedish pressure vessel fabricators are given in Annex H.

Outline of Japanese pressure vessel industry

11.22 Certain of Japan's leading pressure vessel companies are amalgamated with the country's largest industrial complexes. These powerful groups have large captive markets in Japan, and usually own all the raw material sources for pressure vessel fabrication. Their growth rate and profits are high, the modernity of shop equipment outstanding. There is also a continuous and strong research and development activity. The large integrated companies include the following:

Chiyoda Chemical Engineering and Construction Co.
Mitsubishi Heavy Industries
Mitsui Shipbuilding and Engineering Co.
Mitsui Mike Machinery Co.
Hitachi (Engineering) Ltd.
Sumitomo Machinery Co.
Ishikawajima-Harima Heavy Industries
Kawasaki Steel Corp.
Kohe Steel
Japan Steel Works Ltd.

11.23 Another category of pressure vessel fabricators (enumerated in Table H(6) of Annex H) mainly consists of large companies of less importance in the pressure vessel field, either because of less specialisation in pressure vessels or the smaller size of group (or company) in terms of integration. It seems that the research and development efforts and the modernity of equipment of this category of pressure vessel fabricators is also less significant.

11.24 A general feature of the industry is the vital role shipbuilders have played in the development of Japan's industrial plant making industry, particularly in respect of the heavy, massive pressure vessels.

CHAPTER 12

Foreign supply: economic and technical factors

France: commercial factors

12.1 Market conditions (as shown by a historical series of investment figures) in recent years were slightly better than in some other countries, especially Italy and the United Kingdom, where fluctuations of demand were wider. Foreign demand for French pressure vessels especially heat exchangers was continually important, matching the fluctuations of home demand, whose slowing down at times was more than balanced by growing investment in the refinery industry.

12.2 The size of companies and their integration seem to be a limiting factor for the industry's competitive position. Indeed, there are too many small companies, especially if their financial background and research and development capabilities are considered. The association of a few large companies with engineering contractors is, however, regarded as an asset.

12.3 Management and manpower appear reasonably well qualified and flexible. While union problems mainly manifest themselves in periodical wage bargainings and sometimes strikes, co-operation between management and workers is reasonably good. The general wage level is lower than in many other Western industrial countries, but companies are responsible for heavy social contributions. There has been a regular increase in labour productivity in France's industrial investment goods industry and annual turnover per worker in francs has risen in the following way:

1961	48,200
1963	55,700
1965	61,300

12.4 Steel prices are in no case higher than in other countries, and the prices of steel plates destined for the construction of pressure vessels for export do not include internal taxes.

France: technical factors

12.5 Some companies are technically very advanced but the bulk of the industry is no better than the European average. Research and development efforts appear substantial in only a few of the largest companies. In this respect, fabricators working in association with major engineering contractors were in a more favourable position.

12.6 The French construction standards and inspection system are believed to be hindering the fabrication industry's technical progress. This is believed to have hindered its competitive position, although France was already a substantial nett exporter of heat exchangers. For example, the regional inspection services of the Service des Mines were reported to have been known to disagree between themselves, while the design stress is based on the UTS. France's problems were not dissimilar to those of the UK in these respects.

France: institutional factors

12.7 There appears to be no significant governmental intervention with the industry's development in France. There are, however, a few official measures to be considered, destined to improve the industry's competitive position.

12.8 It is the French Government's policy to stimulate mergers to improve the industry's productivity and increase the research and development efforts of individual companies. The movement towards greater integration is, however, very slow, and mainly consists at present of ad-hoc working arrangements and associations (specialisation in research and development, marketing, etc.), and of the creation of common subsidiaries, etc.

12.9 Companies which instal sales agents and offices or manufacturing facilities abroad, are granted considerable tax concessions for the expenditure involved in the setting up and first three months running of such facilities.

12.10 Exports of pressure vessels are stimulated by exoneration from the added value tax on vessels exported and on steels destined for the fabrication of such pressure vessels.

12.11 Export credit and guarantees are granted within the framework of the export-credit system specifically created to facilitate the sale of industrial plant and equipment abroad. The advantages thus granted to the industry are considerable, but procedurial difficulties and the existence of minimum amounts for individual deals reduce to some extent, their practical value.

12.12 In the opinion of French manufacturers and engineering contractors (the main exporters of pressure vessels), the facilities offered in France are not satisfactory, and they think that their foreign competitors receive more incentive (it is perhaps encouraging to note that similar views are expressed by industries in most European countries).

The Federal Republic of Germany: commercial factors

12.13 Home demand has been a powerful support for the development of the industry. Its impressive size (about £70M in 1966) and complexity have been stimulating the industry's expansion in each pressure vessel area. Moreover, the relative stability of total (home and foreign) demand for pressure vessels which the Federal Republic of Germany's industry has enjoyed over the last decade, has given the industry a sound financial situation. This holds true in spite of diminishing profits during the last 3–4 years. The rate of self-financing is still very high in the Federal Republic of Germany's industry, although it varies from sector to sector.

12.14 The industry's size and structure are other features enhacing its competitive position in the home market and abroad. The necessary industrial co-operation in the fabrication of pressure vessels is easily obtainable within the national industry, and very often not only on a national but also on a regional basis. Dished ends and forgings can thus be obtained from companies located in different areas of the country. This co-operation is, however, easiest in the centre of the Ruhr area. Of significance also is the commercial alertness of German fabricators. Two British chemical engineering contractors who had placed orders with German fabricators were impressed by the efficient customer relations. For example, when progressing an order with the German fabricator, the British representative was received with a dossier giving the progress schedule, a sketch of the pressure vessel, and the materials specification for each pressure vessel being made.

12.15 Competition—national and international—has forced the Federal Republic of Germany's industry to modernize continuously its equipment to improve productivity, and one large company was reported to have spent £7M in 1957 on a new fabrication shop. The financial results facilitated capital spending which remained high in spite of the fact that German tax laws did not allow depreciation on an increased replacement value. A machine can be depreciated within three years up to 96% in the UK and up to 72% in France, whereas in Germany the highest permissible figure was 49%. There were only two significant regional exceptions; Bavaria and Berlin. In West Berlin, industrial plant can be depreciated 75% in three years under the Berlin-Hilfe-Gesetz.

12.16 Finally their size and mutual financial links assure to many of the largest companies a significant portion of captive markets for their pressure vessels, as well as captive raw material sources.

12.17 Management and manpower are also strong points. The German industrial managers are mainly specialists of high qualification (principally technical), and usually practise aggressive marketing. The manpower's skills are considered satisfactory, its discipline is reasonable and union problems do not cause much trouble to the management.

12.18 Although the cost of living has been steadily rising for the last 4–5 years, wages and salaries were still somewhat lower in Germany than in many other Western industrialised countries (in 1967 a qualified welder was paid DM 4,20 per hour in Cologne). This was especially true for workers and engineers without executive responsibilities.

The Federal Republic of Germany: technical factors

12.19 The Federal Republic of Germany's pressure vessel design and construction standards appeared to be a further factor improving the industry's competitiveness, as well as the way inspection was organised. It seemed (according to German contractors) that most of the country's pressure vessel fabricators were able to build pressure vessels to foreign design standards. In addition German contractors declared they had not been satisfied with drawings made by most foreign (including British) designers; they were not very clear and were difficult to read. UK fabricators had been unwilling to undertake the design of pressure vessels to the metric system when tendering. The difficulty for Continental companies in reading pressure vessel drawings in the Imperial system had been considered as an important factor in hindering orders for British vessels from German and other Continental contractors and final users.

12.20 One difficulty consisted mainly of getting pressure vessels inspected to foreign design standards. Mutual inspection agreements existed with Italy and France, but did not operate to the entire satisfaction of German pressure vessel fabricators and contractors.

12.21 The quality of steel plates was generally considered satisfactory. Quality inspection was regularly carried out in steel mills, and included X-ray testing.

The Federal Republic of Germany: institutional factors

12.22 The general cascade tax applied earlier was abolished at the end of 1967. The progressive introduction of the Common Market added value tax (TVA) started on 1st January 1968, as follows:

10% from 1·1·1968 to 1·7·1968
11% from 1·7·1968;

and this corresponds to an equivalent tax rebate on exported pressure vessels.

12.23 Direct governmental assistance is in the form of export credit guarantees granted by the Government through the Hermes Kreditversicherungs AG, and this was the basis of West German export finance. This covered all important economic and political risks. Exporters themselves must take a certain proportion of the risk, varying between 10 and 20% according to the type of risk. Five years was generally the maximum term of the guarantee, but recent practice went to eight years. The money was usually put up by the AKA (Ausfuhrkredit Aktiengesellschaft—a consortium of German banks), whose capital had been increased to DM 1,300 M in 1965. The AKA can call on a re-discount line of DM 300M with the Bundesbank for loans for periods of between one and four years, and the exporter had to finance 40% of the value of the delivery himself. Credit from this source costed between 6·5 and 7·5% which, taking into account the exporter's own contribution and of the 0·5% commission per annum the exporter had to pay between the time the credit agreement was signed and the credit was used, gave an overall rate of 7·5 to 8·5% per annum.

12.24 The Federal Republic of Germany's mechanical industries' professional associations seem to be well organised and able to assure valuable services to the industry. The VDMA—Verband Deutscher Maschinenbau Anstalten (Federation of German Machinery Manufacturers)—especially its specialised sections such as the section of industrial apparatuses, provide to their members general information and replies on enquiries. The general information service mainly consists of updating and completing the members' information on markets and technical development. VDMA in Frankfurt employs a large staff of several hundred specialised engineers, economists, etc.

12.25 There are other associations independent of VDMA which group boilermakers and pressure vessel builders. The leading organisation, ie the Fachverband Dampfkessel-Behälter-und Rohrleitungsbau (Specialised Federation of Boiler, Tank, Vessel and Pipework Manufacturers) in Düsseldorf seems to be highly efficient: for instance they had recently completed an exhaustive collection of the world's pressure vessel design and construction standards (their number exceeds 70) which they were analysing to be aware of progress and standards from all over the world to help their members improve their practice. The results of their investigation will be strictly reserved for members.

12.26 The officially recognised inspection authority is the TUV—Technische Ueberwachungsverein (Federation for Technical Supervision). TUV is a German Federal private organisation, grouping 'amtlich anerkennte Sachverständige', ie officially recognised experts, who are the official inspectors for pressure vessels. TUV is a private organisation and acts only as a co-ordinating body for the inspectors. The inspecting competence is granted to each individually qualified inspector. The TUV (ie the inspectors) is given the legal privilege and duty of carrying out inspections of pressure vessels built in the Federal Republic.

12.27 The federal central organisation of TUV is the Vereinigung der Technischen Ueberwachungsverein (Union of the Federations acting in each 'Land'), whose AD—Arbeitsgemeinschaft Druckbehälter, ie its pressure vessel section, elaborates and publishes the AD-Merkblätter, the design and construction standard for pressure vessels. TUV is a member of the Deutscher Normeausschluss (Germany's organisation for standards), the organisation having the ultimate responsibility for standards. Deutscher Normeausschluss is also a private body, grouping the TUV, representatives of fabricators, end-user industries and competent State authorities.

12.28 Modifications to the design and construction standards and inspection system appeared to be not easy, because of conservatism, but could be made within a reasonable time. Construction rules were not incorporated in law, and the responsible organisations were not under the control of public authorities. In the opinion of German fabricators and contractors the situation was much more favourable in the Federal Republic of Germany than in France in this respect. New regulations were being pressed by German pressure vessel fabricators, and it is taken for granted that the new rules proposed will be shortly adopted. Steels for pressure vessels were inspected at the mill and the mill delivered a 'certificate of conformity' to required standards, which was accepted usually without problem. Foreign steels were inspected individually by DIN.

12.29 As to inspection practice, all pressure vessels, either for the home market or for exports, are inspected by TUV, whose competence cannot be delegated. Supplementary inspection, if asked for by client, may be carried out by Lloyd's, Veritas, etc. For export-bound pressure vessels, inspection may be made to foreign design standards. Mutual agreements exist between Germany, Italy and France.

12.30 A special system is in force in two 'Länder' of the Federal Republic of Germany. In Hesse and Hamburg there is a Technische Ueberwachungsamt (Bureau for Technical Supervision), controlled by the 'Land'. These TUA have the same competence here as TUV in the other 'Länder'. TUV is, nevertheless, authorised to carry out inspections in Hamburg and Hesse when called on for special inspection. In such cases, their conclusions are usually accepted by the Land's TUA and the latter delivers the necessary inspection certificate. These certificates delivered by TUV or TUA are transmitted to the 'Gewerbaufsichtsamt', ie industrial supervision office who, in its turn, gives the authorisation to operate.

Italy: economic factors

12.31 The reasons for the allegedly strong competitive position of Italian fabricators can be classified both as structural (modern shops and efficient use of manpower) and as conjunctural (in relation to particular market conditions). It is believed that conjunctural reasons have been stronger than the structural towards explaining this competitiveness. Reference is now made to Fig. 12(1):

Line 1 represents the investment in chemical and petroleum plant, ie the sectors of direct demand for pressure vessels, and this shows the abrupt reduction in investment in 1964. This occurred in connection with the evolution of the general economic development of Italy growing at a fast pace since the war, which experienced an accelerated growth between 1959 and 1962 and a reactive slowdown of the growth rate in 1963 and 1964.

Line 2 represents the capacity of steel plants in Italy. Starting from about 1959–60 an important reorganisation and expansion programme was entered into by the State-held IRI-Finsider Group (which accounts for over two-thirds of Italian steel production).

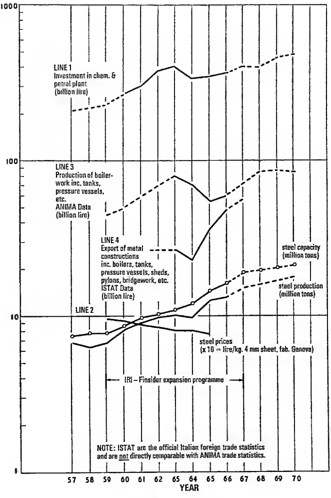


Fig. 12(1). Market factors – Italy

This was in full swing in the years of the 'recession'—the first LD furnace was started in November 1964. The effect may be seen on prices of the expansion in capacity. Furthermore the general slowing down of industrial activity reduced demand for steel and as steel deliveries were shorter this further helped the fabricators;

Line 3 shows the production of boilers, vessels, tanks, etc. (ANIMA data). The Boilermakers' Association Reports, while giving no figures before 1963, state that production had been steadily rising in the period since 1957, to reach a peak in 1963 which had not been surpassed. The sharp decline in production can be noticed in the years 1963–5, a direct consequence of lower domestic demand;

Line 4 shows the exports of the category of products in which pressure vessels are included as well as other heavy metal fabrication (ISTAT data). The rise in the years 1965–6 results from contraction of domestic demand and the low price and ready availability of steel.

12.32 The particularly sharp rise in 1965 of deliveries abroad followed the search for work in 1964. In the winter 1964–5 Italian pressure vessel prices were the lowest and deliveries the shortest.

12.33 Exports continued to increase through 1966, and, for example, in the first four months of 1967 export of heat exchangers were already twice as much as the amount exported during the same period the year before. This hysteresis, which is typical in economic circumstances such as these and which was feared by some as 'an acquisition by Italian fabricators of a taste for export', was also due to the fact that international clients had come to be acquainted with Italian fabricators and their good prices and deliveries. Italy's stake in the international market will, of course, change as a function of the evolution of its internal market.

12.34 Some factors that may influence Italian pressure vessel competitiveness in the future are as follows:

overall investments in the chemical and petroleum field are estimated to continue to grow annually even though not so much as in 1959–63 period. This will be mainly due to the slowing down in new investments in the petroleum field (Italy's refining capacity is already 1½ times that of the UK);

wages are increasing, the trade unions are growing stronger, the psychological background of labour productivity may change as general standards of living improve.

12.35 General satisfaction was expressed by Italian fabricators on the quality and service by the Italian steel mills, principally ITALSIDER. All steel for pressure vessels for the domestic market is ultrasonically tested in the mill by ANCC personnel.

12.36 Steel is bought abroad, particularly from Common Market countries, although stainless steel was imported from Sweden and steel tubes from the United Kingdom. However, Italian mills were said to be flexible in the manufacture of steels to meet foreign design standards and had many licences to make foreign proprietary brands of steel.

12.37 With regard to steel prices, inevitable reluctance was encountered on the subject of real prices particularly with fabricating companies linked to steel manufacturers. However, the impression was formed that pressure vessel fabricators had obtained up to 5–10% quantity discounts, as well as loyalty bonus, rebates for certain global annual tonnages, etc. which could amount to 5–10%.

The following table gives examples of typical *domestic* prices of Italian pressure vessel fabricators:

Type of vessel	Steel	Total weight	Price range £/ton
Vertical reactor including internals	C, ½% Mb	45 tons	270–314
,,	C, ½%Mb	20 tons	320–415
Horizontal storage vessel	C	10 tons	160–180
,,	C	2.5 tons	200–250
Open top tank	C	3·5 tons	170–230
,,	C	1 ton	315–340

Source: Interviews in Italy with contractors and final users

12.38 With regard to delivery, it appeared that many fabricators tended to keep stocks of most current material. Mills also held stocks of standard steels. Clearly these stocks were a useful buffer against emergency situations but were costly to maintain. Manufacturing deliveries which were about 1–2 months in 1964–65 had lengthened considerably due to the increase in demand and an example was quoted (in 1967) of C steel plate over 20 mm in thickness offered on a 4 month delivery period.

12.39 Italy uses a cascade type tax levied as a percentage (generally 4% on most goods) on each sale of goods. The final levy therefore on finished goods adds up to a sizeable amount. There was considerable discussion with regard to the replacement of a cascade tax by the TVA system, but no definite decision had yet been taken in this matter by early 1968.

12.40 For exports, certain taxes are reimbursed (purchase tax, etc.) and the amount of IGE reimbursed on exported pressure vessels is as follows:

Stat. code 8401 (boilers)	7·50%
Stat. code 8402 (boiler accessories)	7·50
Stat. code 8417 (heat exchangers)	6·25
Stat. code 7322 (refinery towers, pressure vessels, other metal fabrication)	7·80

12.41 In addition to the IGE specific rebate, other taxes or special levies are reimbursed or conceded for products made with Italian steel (around 5%). A special subsidy is given tied to the quality of Italian manufactured steel for all exported products, for destination outside the European Economic Community. This subsidy—'Rimburso Siderurgico'—was established by law (N. 639 5 July 1964) and varies between 15 lire/kilo and 220 lire/kilo, depending on the type of steel and type of product manufactured from it. For a carbon steel vessel, the subsidy would be in the region of 20 lire/kilo, approximately 5% of the value. For a stainless steel vessel, the subsidy would be about 40 lire/kilo.

12.42 Taken together, therefore, these export rebates of some 10–15% (combined with the price 'shading' of Italian steel suppliers of some 5–10%, reflecting a final pressure vessel price advantage of 3–6%), could represent a price advantage of from 13–20% for export orders. It is hard to be specific about these matters, for the extent of the export price 'reductions' has varied in conjunction with Italian domestic demand for pressure vessels. As many of the above rebates are available to the Italian steel industry for direct exports the system is, in effect, equivalent to offering Italian manufacturers steel at export prices for fabrication of pressure vessels for export. The variations in price reduction here referred to are primarily the variations in price affected by the Italian fabricators in response to variation in domestic Italian demand for pressure vessels. There appears to be no feedback (to take account of changes in market conditions) on the export tax rebates (IGE and RS). Any alteration that might occur to RS might only arise from the planned reduction of tariff barriers to EEC.

Italy: alleged dumping by Italian pressure vessel industry

12.43 Because of the confused state relating to the question of alleged dumping of vessels by Italian fabricators on the UK market, the present section discusses the various factors involved.

Definition of dumping

12.44 Before defining dumping, it should be appreciated that different definitions may be used according to whether the goods in question are in series-production or are of a one-off or jobbing nature. The majority of pressure vessel fabrication is of the jobbing type.

12.45 Dumping may arise in Country A with imports from Country B under the terms of GATT whenever:

(a) goods are sold in Country A at a price less than that for equivalent goods sold in Country B's home market, *or*

(b) goods are sold in Country A at a price less than that for equivalent goods sold in other countries to which Country B has exported, *or*

(c) goods are sold in Country A at a price less than a 'hypothetical price' for equivalent goods hypothetically sold in Country B's home market; the hypothetical price being determined by a fair and reasonable estimate of materials and production costs together with a reasonable profit.

Notes: *Class* (a) dumping may occur with series produced goods when identical goods are sold on the home market of the exporting country (B in this case).

Class (b) dumping may occur with series produced goods when identical goods are sold on the home markets of other recipient countries but not on the home market of Country B.

Class (c) dumping may occur with 'one-off' or jobbing production, whenever similar (but not identical) goods are sold in Country A at prices which are substantially less than a 'hypothetical' price for the goods in Country B's home market.

12.46 For dumping of goods produced by jobbing fabrication it will, almost inevitably, be necessary to adopt the class (c) dumping definition.

12.47 In order to take action under GATT it is understood to be necessary not only to demonstrate that dumping has occurred, but also that material injury either has arisen to the industry involved or is likely to occur to this industry if dumping were to continue. This would involve the assessment of the degree of material injury (or threat of injury) to the UK fabrication industry should dumping continue for a period of, say, several months or more. Furthermore, it would be necessary to assess what the position would have been had the dumping not occurred. Thus if competitive prices from yet a further fabrication industry abroad still undercut the UK fabrication industry prices, then the material damage could still occur to UK industry regardless of whether or not action was taken against alleged dumping by the original foreign fabrication industry.

12.48 It is understood that anti-dumping evidence for action under the Tariff Act may only be put to the Board of Trade by industry or its representatives. In order to encourage the UK industry to consider the preparation of evidence for such action, the Board of Trade contacted TIPA in August, 1967, and invited TIPA to gather such evidence as was needed. The BOT suggested that TIPA select a particular type of pressure vessel to use as a 'pilot' or test case, and to obtain a price for it on the Italian home market as well as obtaining a price for it when exported to the UK. The BOT were awaiting (April, 1968) for TIPA to act so that BOT may themselves consider whether action under GATT might be initiated.

12.49 TIPA are reported to acknowledge the helpful attitude of BOT, but point out that the amount of information required by BOT before they can take action is very considerable and extremely difficult to obtain. The various pressure vessel customers in the UK (end-users and contractors) have knowledge of the Italian pressure vessel export quotations but appear reluctant to disclose this information, even in strict confidence, to TIPA. The TIPA are reported to feel that customers should be asked to disclose this information to help with an anti-dumping case. It might be desirable, for example, to ask for materials/production/transport/overhead cost breakdowns when customers sought quotations from abroad. The TIPA had not gone back to BOT by April, 1968 as it was felt that devaluation might substantially reduce the import of Italian (and other foreign) vessels into the UK. With this in mind TIPA were to seek information from the BOT on pressure vessel imports into the UK from January 1968 onwards (under the *new* Customs and Excise headings) to ascertain whether imports had been reduced substantially as a result of devaluation.

Export rebates

12.50 There are two main areas of export rebate in Italy:

(1) Rebate of IGE on exported goods (this is a cascade or general turnover tax of 4% on each sale of goods). The rebate for *pressure vessels* is between 6–8% depending upon the type. It is understood that, in principle, this rebate is reasonable under GATT regulations.

(2) Rebate of Customs Duty for all mechanical goods, this is a special subsidy tied to all exported products made with Italian steel and is called the 'Rimburso Siderurgico' (RS). This was reportedly established originally to protect the Italian steel industry from the initial fierce competition resulting from joining the EEC. The RS for goods exported to the other five members of EEC has been reduced to a nominal level of one-fifth the original level of the RS but the original full level is still applied to exports outside the EEC. It may be seen that the original basis for the RS rebate is no longer applicable, and it is understood that the continued operation of this particular rebate may be considered to be an export subsidy and thereby an infringement of GATT.

12.51 The type of measure that the UK could take, for example, would be to impose a special import levy (additional to the general 15% import surcharge for pressure vessels) which would act as countervailing import duties in respect of those particular goods the import of which were, or could, injure the UK fabrication industry.

Alleged 'hidden' government subsidies

12.52 There have been suggestions that the Italian Government provided 'hidden' subsidies for exports. However, other than the declared subsidies (of IGE and SR etc. noted above) no evidence was found to suggest that the Italian Government was providing 'hidden' further subsidies for export goods.

12.53 A major factor in the highly competitive export prices from Italy was the need for Italian fabricators to cut severely their export prices—even to the extent of making a loss on certain individual orders—in order to keep their shops working following the decline in home Italian demand. Fig. 12(1) shows this sequence of events very clearly: in 1963 a sharp decline in investment in chemical plant (line 1); in 1963–4 a very sharp decline in production of boiler work (line 3); in 1964–6 a very sharp increase in exports for metal construction including boilers and pressure vessels (line 4).

12.54 It is unlikely that Italian fabricators would diminish their export sales drive, even though Italian home market demand was again increasing, for at least four reasons:

(1) the Italian fabricator has developed a desire to export and it is unlikely that the substantial sales effort and goodwill developed with customers outside Italy during 1964–7 will be lightly discarded;

(2) the utilisation of Italian fabrication capacity was severely cut from 95% during 1962–3 to 61% in 1965 (see Table 10(5), line 2). In spite of this the installed capacity was being increased each year and, during the period 1965–7, the utilisation factor had risen to 65%. There is, therefore, considerable incentive for the Italian fabricator to continue to exploit export markets to the utmost so as to increase the utilisation factor above the (low) figure of 65%;

(3) the widespread attitude of the employer-manager-owners of Italian fabricators to keep their workforce engaged at all costs even when it meant (in the short term) making a loss in accepting an order. The Italian religious background supported this attitude;

(4) the substantial margin of 'loss' the employers would be willing to take in terms of the 'opportunity cost' of the alternative which is to sack part of their workforce. This 'opportunity cost' is the total social security payments the employer would have to make in compensation to those he sacked. Thus in the first three months of redundancy the employer is understood to have to pay 64% of the average wage for the last three month period of employment, plus a lump sum of one month's pay for each year of service. Following redundancy, the Italian Government then provides half-pay for six months.

Sweden: economic, technical and institutional factors

12.55 It does not appear that home demand for pressure vessels has been a favourable factor for the development of Sweden's pressure vessel fabrication industry: the size of domestic demand has not been sufficient to support more than a few significant specialised pressure vessel builders, such as Uddeholms. This was particularly important in respect of the manufacture of dished ends, flanges and nozzles and, if the industry's size were greater, Uddeholms would probably not fabricate the dished ends it mainly used in its own fabrications; instead there would be a wider co-operation between the country's fabricators. Uddeholms import from Denmark (as do probably all the other significant Swedish pressure vessel fabricators) all the dished ends of a size larger than their own ends, while all flanges and nozzles are imported mainly from the Federal Republic of Germany.

12.56 Technical factors are favourable for the Swedish pressure vessel industry. Steel plates are of high quality, and the design standard and inspection system were not hindering progress and productivity in production.

12.57 Management seems to be well organised. Managers and sales managers are usually engineers or have a good technical education. Labour flexibility appears good and relations between management and the union reasonable. A strong trade union movement has pushed wages up aggressively, yet left management free to seek efficiency even when this has meant lay-offs from individual companies. Special productivity agreements have not been needed.

12.58 These factors explain the high exports of Uddeholms, which have been noted particularly in the context of the British market.

Japan: economic factors

12.59 The development of home demand for pressure vessels has led to the continuous growth of the country's pressure vessel industry. Two main cycles may be distinguished in the post-war period: (1) the economic recovery when the main emphasis was on the fertilizer industry and its equipment needs, and (2) the acceleration of equipment investment in the petrochemical industry.

12.60 The structure of the industry has also been a powerful factor in the development of pressure vessel fabrication. Apart from a significant portion of captive market and raw material sources due to the integration of the industry and the close co-operation with engineering (Japanese and foreign) organisations, two principal advantages which the industry has been enjoying, can be distinguished:

(1) a considerable part of the industrial plant (hence pressure vessel) industry originated with shipbuilding companies, as a result of some similarities between shipbuilding and industrial plant engineering and construction. Of these similarities the most important for pressure vessel construction are the following:

(a) a shipbuilding enterprise requires large and assorted types of equipment;

(b) a shipbuilding shop is capable of manufacturing very large types of machinery and equipment. (It is, for instance, current practice to assemble huge refinery towers on the grid-iron of a shipbuilding slip. After launching into sea water it is shipped outside with a tug-boat and hoisted aboard a cargo ship by floating crane);

(c) large shipbuilding enterprises have long experience in international transactions and also have complete networks for providing after-service;

(d) shipbuilding companies are usually large and have powerful financial backing;

(2) the Japanese mechanical industry has been enjoying an abundant supply of manpower: between the two main fast developing industrial sectors—the mechanical

and chemical industries—the one with the much higher capital/labour ratio is the mechanical industry.

12.61 The faculty of management to adapt to new technologies as well as to modern selling methods seems to be excellent. There are, however, still some complaints expressed in the industry about shortage of technologists and sometimes insufficient experience of engineers, especially concerning engineering and construction of petrochemical equipment.

12.62 As to manpower, skills are considered satisfactory. There is flexibility in the trades in industrial manpower, and practically no union problems.

Japan: technical factors

12.63 The technical progress of industry is largely a result of the research activity of the large companies. Most large companies have their own research centres and laboratories where basic and applied research is carried out, often in close co-operation with universities. Co-operative research programmes are carried out by ad-hoc company groups in associated sectors aimed at developing new processes and/or products and equipment, etc. Technical co-operation between chemical plant (and pressure vessel) producers and plant and process engineers is being developed intensively both nationally and internationally (mainly with the USA).

Japan: institutional factors

12.64 It seems that the Ministry of International Trade and Industry (MITI) plays a significant and useful role in the direction of Japan's economy, especially through its policy concerning industrial investments in selected sectors and the development of export oriented industries.

12.65 The new Japanese export promotion plan inaugurated by MITI is designed to resolve Japan's international balance of payments problem and goals will be established for each industry. The mechanical sectors, which are already a significant part of Japanese total exports, were expected to rise by 15·6% in 1967.

12.66 MITI's influence has moreover been decisive since the early 1960's in stimulating the development of co-operative research in different industrial sectors, especially between chemical, petroleum and chemical engineering firms, initiated by the Institute of Industry and Technology of Japan. The MITI actively advocated legislation (voted in 1965) for co-operative temporary industrial research groupings. The main objectives of this law are the following:

(1) to allot research subsidies by the Government in an effective manner;

(2) to avoid duplicating investments by individual companies in similar research work or facilities;

(3) to grant special depreciation rates for research facilities;

(4) to give tax exemption;

(5) to share equally risks and profits among the participating companies.

In two years (1965 and 1966) approximately 20 joint research groupings have been organised for the development of new technologies in various fields of industry.

CHAPTER 13

Foreign demand: EEC

France

13.1 According to French contractors' views, at least 90% of French pressure vessel exports were directly due to their activities. This evidence from the contractors was substantiated by interviews with the individual pressure vessel fabricators. CMP seems to be the only direct pressure vessel exporter. The proportion in respect of imports is likely to be the same. French manufactured pressure vessels sold on the domestic market similarly pass through the hands of contractors, to an estimated proportion of 75 to 80%. The proportion may even reach 100% in the case of refinery installations.

13.2 Some of the largest pressure vessel builders are linked with engineering contractor companies or have engineering divisions. The examples of Franco-Belge and Schneider-Creusot are typical in this respect.

13.3 The main criteria for choice between pressure vessel fabricators by contractors when ordering are the following in order of decreasing importance: quality and confidence in quality; relationship client-fabricator; price and delivery. Special relationships, usually financial, between clients (the final users) and fabricators often interfere with the criteria of choice by the contractor for his pressure vessel supplier. In the opinion of French contractors the cost-plus engineering contract is the best formula to protect the mutual interests of all the contracting parties.

13.4 During the period 1961–5 the average annual growth rate of the French chemical industry was 9%. According to the 5th National Economic Plan, the annual growth rate will be 8·3% between 1966 and 1972. During the period 1960–5 the growth rate of the refinery industry was considerably higher, and is reflected in the evolution of investment in this sector as shown in Table 13(1).

TABLE 13(1)

Equipment investment in the French chemical and refinery industries

(In £M adjusted to 1966)

	1960	1961	1962	1963	1964	1965	1966	1972
Chemical industry	92	101	115	123	128	153	170	240
Refinery industry	18	—	—	61	—	83	65	65–70

Sources: Commissariat Général du Plan, French national statistics, etc.

13.5 Within the chemical industry, ammonia, plastics and petrochemicals in general are scheduled to have the fastest growth. A slowing down in investment in the refinery industry is predicted up to 1970, owing to the large new capacities created in the preceding period. The gas industry will be mainly developed by a rapid increase in the consumption of natural gas, which implies a significant use of storage tanks.

13.6 The vessel content of equipment investment in the chemical and refinery industries in 1966 and forecast for 1972, is estimated at £26·5M and £35M respectively. These estimates are derived by applying a vessel to equipment investment percentage of 11·3%.

The Federal Republic of Germany

13.7 German contractors estimate that at least 70% of the pressure vessel sales in the Federal Republic of Germany are carried out through their services. The share of pressure vessels sold through contractors on the domestic market is much less than on export markets: practically all pressure vessels exported go into turnkey plants installed abroad by contractors.

13.8 As to imported pressure vessels installed in the Federal Republic of Germany, their share in total domestic demand is less than 5%.

13.9 The usual pattern of commercialisation from pressure vessel fabricator to final user is classical: pressure vessel builder-contractor-final user (German or foreign). The contractor's place is often held by more than one contracting company depending on the size and complexity of each individual project and on the processes required. In the case of very large turnkey jobs, an ad-hoc consortium of several companies is organised. This is current practice with one of the largest contracting companies in the Federal Republic of Germany.

The investment in the three large pressure vessel user sectors (chemical, refinery and food industries) for the period 1962–6, and an estimate for 1972, is given in Table 13(2).

TABLE 13(2)

Investment in three pressure vessel user sectors in the Federal Republic of Germany

(Figures in £M)

	Chemical industry		Refinery industry		Food: sugar, beverages and tobacco	
	Total investment	Hardware (at 50%)	Total investment	Hardware (at 50%)	Total investment	Hardware (at 50%)
1962	209	105	73	37	191	95
1963	209	105	—	—	—	—
1964	246	123	—	—	—	—
1965	246	123	—	—	—	—
1966	345	172	123	62	254	127
1972	537	270	200	100	327	163

Source: Chemical Journal Sources and Interviews with German engineering contractors

13.10 In the above table, the hardware content of total investment has been estimated at 50% for all three basic industries. This permits calculation of the hardware (and thereby vessel) content for the three groups of industries on a basis similar to that used in one of the demand analyses used for the United Kingdom in Chapter 6.

13.11 The vessel content of investment in hardware was estimated as a result of interviews with German contractors. The following table gives these percentages together with the domestic German demand for vessels for 1966 and 1972:

	Vessel content in hardware (%)	Demand (£M)	
		1966	1972
Chemical industry	12	21	33
Refinery industry	12	7·5	12
Food etc. industries	3	4	5
TOTAL DEMAND FOR THREE SECTORS		32·5	50

Source: Table 13(2)

13.12 If the same vessel content of investment in hardware in 1966 for the three industry groups is considered for 1972, these sectors' total demand for vessels will reach £50M by 1972.

Italy

13.13 About 70% of Italian pressure vessel production goes through the hands of three contractors: Foster Wheeler, SNAM and CTIP. The rest goes through other major international contractors who are active shoppers in Italy, and direct end-users such as Montedison (mainly), Rumianca, SNIA and SIR.

13.14 Table 13(3) gives total investment figures in the Italian chemical and allied industries and in the petroleum industry.

TABLE 13(3)

Investment in main pressure vessel user sectors in Italy

		1966	1967	1968	1969	1972
Chemical and allied	(billion lire)	258·5	331·9	376·7	423·7	450·0
Petroleum	(billion lire)	114·3	77·6	29·2	45·9	40·0
TOTAL	(billion lire)	372·8	409·5	405·9	469·6	490·0
	(£M)	210	235	230	270	280

Source: CONFINDUSTRIA

13.15 It may be noted that the reduction in refinery investment will be compensated by the large increase in investment in the chemical industry. Oil refineries have been required, by law, to have a 30% reserve capacity. This law is now under revision. If it were abolished, new investment in 1968–9 would be less than that forecast by CONFINDUSTRIA.

Benelux

13.16 In *Belgium* the development of investment in the chemical industry has been as follows during the period 1961–5:

(Figures in £M)

	1961	1962	1963	1964	1965
Investment in the chemical industry	23·2	29·3	28·2	30·3	43·0

Source: Die Chemische Industrie, and Amsterdam-Rotterdam Bank

13.17 In the case of the *Netherlands* precise figures for equipment investment are only available for 1964 and 1965, and are as follows:

1964: £43·3M
1965: £56·4M

13.18 An important factor affecting chemical and petrochemical investment in both countries will be the recent preference of US chemical companies for investment in Belgium and Holland, amongst other factors this has arisen from the EEC expansion programme. The American investments are most likely to affect the petrochemicals. Some forecasts were made a few years ago which have shown themselves to be rather over-optimistic by current figures. In spite of this, it is believed that these investment figures will become of significant size in the future.

CHAPTER 14

Foreign demand: EFTA

United Kingdom

14.1 Investment in the UK has been dealt with in Chapter 6.

Sweden

14.2 As already shown by the foreign trade factor, foreign demand for pressure vessels made in Sweden is not important. Home demand can only be estimated, as no data was available either of demand or of vessel output.

14.3 The equipment investment in the Swedish chemical industry developed as follows in recent years:

	1964	1965	1966	1967
Equipment investment in £M	17·0	25·2	31·2	36 (Est.)

Source: The Swedish Economy 1967, and Svenska Handelsbanken

14.4 The application of a vessel ratio of 15% to these equipment investment figures gives a vessel demand of approximately £4½M.

Austria, Denmark, Norway, Switzerland

14.5 Table 14(1) gives the investment in the chemical industry during the period 1963–5. To obtain a very approximate vessel content, the figures may be multiplied by about 7%.

TABLE 14(1)

Investment in the chemical industry in ETFA countries

	1963	1964	1965
Austria	£11·2M	£11·9M	£10·0M (Est.)
Denmark	12·9	16·8	18·6
Norway	14·3	13·7	10·6
Switzerland	26·0	29·0	31·4

Source: OECD, professional publications

Portugal

14.6 No dependable data on investment in the Portuguese industry is available. The main developments in the industry's capacity in 1963–4–5 concerned the pharmaceutical industry, where growth is high. The problem of installing a new petrochemical industry in the north of the country, based on new oil refining facilities to be created there has been studied recently. The new complex would also comprise one other chemical product.

CHAPTER 15

Foreign demand: COMECON

General

15.1 There is a significant expansion in demand for chemical and refinery plant equipment in the whole Comecon area. It stems either from the incomplete structure of the chemical industry or from the insufficient capacity of the chemical industry in relation to general industrial development. The present structure of the chemical industry in the USSR has arisen from the history of past planning, particularly in respect of plans to derive textiles, plastics and refined products from basic chemical feedstocks. The shift from coal to petroleum, undertaken only a few years ago, as well as to gas more recently, continues to affect the region's needs for refinery and petrochemicals plant equipment.

15.2 Production and investment in chemicals, petrochemicals and fertilizers is given high priority in national economic plans for 1966–70 in the whole area, except East Germany where the main emphasis is laid on the mechanical (heavy and light) industry.

15.3 Table 15(1) gives estimates, in US $M, of chemical equipment annually needed by Comecon countries in the 1966–70 period.

TABLE 15(1)

COMECON demand for chemical equipment

	Chemical equipment required per year (US $M)	Equipment to be purchased in Western countries per year (US $M)
USSR	1,800	400–500
Poland	110	40–50
Czechoslovakia	70	25–30
East Germany	120	50–60
Rumania	100	40–45
Hungary	60	25–30
Bulgaria	35	20

Source: Estimates based on Plan estimates and other sources

15.4 The Comecon countries openly publish the amount of equipment to be purchased in Western Countries so as to encourage free competition (with its associated price competitiveness) between the Western countries. Furthermore, the Comecon countries do not indicate the breakdown of this expenditure between various Western countries for the same reason—price competitiveness. This is all part of the systematic shopping policy by the Comecon bloc. There is urgent need for the UK to look at the 5 year plans of the various Comecon countries in order to anticipate their potential market needs—this review could be carried out at both industrial and governmental level.

USSR

15.5 The growth target of industrial production for 1966–70 is 8·2% per year, and 8·5% for the output of investment goods. In Table 15(2) are given the 5-year *annual* average growth rates in the main sectors of the chemical and petrochemical industry in the period 1961–5 and 1966–70.

TABLE 15(2)

Annual growth rates by industry: USSR

Industry	1961–65	1966–70
Petroleum	10·4%	7·6%
Inorganic fertilizers	17·6	15·2
Gas and natural gas	22·4	13·0
Refinery	8·5	10·0
Plastics	19·8	21·8
Synthetic fibres	14·1	14·6

15.6 Two specific sectors may be mentioned separately:

the USSR was considering in 1967 the purchase in Western countries of a number of large-scale ammonia plants. Enquiries were made to leading British chemical contractors;

the gas industry is another market for equipment (the 13% average annual growth for 1966–70 indicated above seems to be too low). However, as this is essentially natural gas distribution, pressure vessel demand is essentially linked to storage and not to process plant.

15.7 According to a recent estimate (Chemical Age, December 1967) total capital investment (equipment *and* sitework) in the Soviet chemical industry will average £1,040M per year during the period 1965–70.

15.8 The main state organisation for chemical plant and equipment imports is:

TECHMASHIMPORT, Moscow—I—200

Poland

15.9 The planned growth rate for 1966–70 is 14% per year for the chemical industry as a whole. Equipment investment will amount to US $700M in five years.

15.10 Main planned capacity changes are linked to fertilizers:

	(Output capacity in million tons) 1966	1970
Nitrogen	0·6	1·2
Phosphate	0·38	0·72
Sulphur (1967)	0·6	1·0
Ammonia	0·4	1·2

15.11 The capacity of the Plock refinery will be increased from 3M tons/year to 6M tons/year.

15.12 It is estimated that about half of the equipment needed will be imported from Western countries (UK, France, Federal Republic of Germany, Italy and Austria). At present there is a close working relationship with France's Pechiney (processes) and Schneider-Creusot (equipment).

15.13 Main state organisation of chemical plant and equipment imports is:

POLIMEX, Ul. Czackiago 7/11, Warsaw

Czechoslovakia

15.14 Although the country is currently producing more than 100,000 tons per year of equipment for the chemical industry, import requirements are considerable, especially for the plastics and petrochemicals industry. In this latter a significant expansion is predicted, especially for olefines and their processing. Carbon disulphide and butadiene production from petroleum is being developed. Production of epichlorhydrine and bisphenol will also be launched by 1969–70. The capacity of the 4M tons/year Slovnaft refinery will be increased and units to produce 69,000 and 35,000 tons/year ethylene and propylene respectively will be installed. A £3M contract was awarded in 1967 to a British contractor for the delivery of a 40,000 tons/year paraxylene plant to be installed at Slovnaft.

15.15 The main state organisation for chemical plant and equipment imports is:

STROJIMPORT, 1, Vaclavske Namesti, Prague 1

East Germany

15.16 While an 8% annual growth target has been fixed for the country's industry as a whole, that for the chemical industry is only 7%. It is however estimated that East Germany may need to buy as many as 30 chemical plants in Western countries, in addition to its own chemical plant production, which is mainly exported to the USSR.

15.17 The main state organisation for chemical plant and equipment imports is:

CHEMIEAUSRUESTUNGEN, Mohrenstrasse 53/54, Berlin W 8

Rumania

15.18 The principal aim of the 1966–70 plan is to realise a fourfold increase in petrochemical production compared with 1965. The main investment plans concern:

(1) a new 3M tons/year oil refinery at Pitesti, to be partially commissioned in 1968;

(2) a new 300,000 tons/year plant for crude oil processing at Suplacu-Barcan to be commissioned at the end of 1968:

(3) the installation of not less than 70,000 tons/year new capacity for the production of synthetic fibres and plastics.

15.19 The main state organisation for chemical plant and equipment imports is:

MASINIMPORT, str. Mihail Eminescu 10, POB 17, Bucharest

Hungary

15.20 In the 1966–70 plan the development of the chemical industry is given the highest priority. About US $400M will be spent on investment in this industry. Imports of chemical plants are heavily increasing from both Eastern and Western sources. Production of chemicals is to grow about 10% annually between 1966 and 1970, especially:

	Production 1965	*Capacity* 1970
Fertilizers	265,000 t	650,000 t
PVC	15,000 t	80,000 t
Polyethylene	15,000 t	48,000 t
Polyamide	—	3,500–5,000 t

15.21 The capacity of the 1·5M tons/year oil refinery at Szaszhalombatta will be doubled by 1970.

15.22 The main state organisation for chemical plant imports is:

CHEMOLIMPEX, 64, Nepkoztarsasag utja, Budapest VI

Bulgaria

15.23 During the 1966–70 period, about US $160M are to be invested in the country's chemical industry.

15.24 The capacity of the 3M tons/year oil refinery at Bourgas will be doubled by 1970. Other new capacities planned for 1967–70:

400,000 tons/year ammonia plant;

600,000 tons/year 100% nitrogen fertilizer units;

180,000 tons/year phosphoric acid;

unknown but sizeable increase in capacity for nitric and sulphuric acid.

15.25 These form part of a complex plant, estimated at US $42M. The equipment will be bought mainly in the USSR and possibly partly in the UK.

15.26 The main state organisation for chemical plant imports is:

TECHNOIMPORT, 10, Graf Ignatiev Street, Sofia

CHAPTER 16

Foreign demand: Latin America

General

16.1 Three main features characterise the Latin American chemical industries and their development:

(1) In many countries the size of chemical and petrochemical plants is small compared with modern standards and some plants are uneconomical because they were built to serve small national markets;

(2) Although the raw material basis of the industry is excellent in some countries, the supply of basic chemicals and basic petrochemical products is understood to be insufficient;

(3) The investment in the industry, hence its development and the creation of a further financial basis for future growth, greatly depends on international sources of investment capital such as:

(a) from the USA:
through the official US Agency for International Development and the Alliance for Progress programmes;
the US Export-Import Bank;
American private capital;

(b) from international sources:
the World Bank itself for infrastructure investment;
the International Finance Corporation (a World Bank subsidiary);
West European capital.

Argentina

16.2 The average growth rate of output in the country's chemical industry will probably increase enormously between 1966 and 1970 compared to the average of the preceding period. Indeed, from £136M in 1960, the total value of the industry's output increased to £186M in 1965 and, according to planned new capacities, it will reach £500M by 1970. This development of the industry will be mainly due to petrochemicals.

Brazil

16.3 The total output of Brazil's chemical industry increased in value by 147% between 1960 and 1965, ie from £278M to £410M. No figures of investment were available for this period.

16.4 The following capacity increases are planned between 1966 and 1970:

	capacity 1966	*planned capacity* 1970–71
Inorganic chemicals, total '000 tons	1,479	2,480
Organic chemicals, total '000 tons	446	1,040

16.5 Only consumption and planned consumption figures were available concerning fertilizers:

	Consumption 1965	*Planned consumption* 1970
Phosphate fertilizers, tons	71,000	115,000
Potash fertilizers, tons	100,000	160,000

Chile

16.6 According to the first CEPAL-Plan, the country's total production of chemicals was to reach, in value, £46M. The actual value of the 1965 total output was £32M.

16.7 Chile's economic plan for the period 1961–70 heavily emphasised the growth of the chemical industry, and total investment planned for the 10-year period amounted to £54M. No information is available concerning the amount already spent, but it seems that the bulk of it was still to be invested in 1966.

Colombia

16.8 The total value of chemicals produced increased from £34M in 1960 to an estimated total of £50M in 1965.

16.9 Total output of *inorganics* amounted to about 320,000 tons in 1964, and according to new capacities being installed (spring 1967) and planned, total capacity will reach 1·2M tons per year by 1970–1.

16.10 The petrochemical industry is at its very beginning, and the main problem in the development of the plastics and synthetic fibre industry is the lack of basic petrochemicals.

Mexico

16.11 Mexico's chemical industry has developed in recent years as follows:

Year	1961	1962	1963	1964	1965
Total output in £M	208	247	271	323	344

16.12 It is estimated that the total value of production will amount to £520M by 1970. The structure of output will be then the following:

	Share in total (%)	*Output* (£M)
Petrochemicals	22	114
Pharmaceuticals	19	99
Dyestuffs	5	26
Heavy chemicals fertilizers and others	54	281
TOTALS	100%	£520M

16.13 The following are the main new capacities to be installed by 1970–1:

Fertilizers	330,000 tons
Dodecylbenzol and others	80,000 tons
Isopropanol	24,000 tons
Acetaldehyde	24,000 tons
Ammonium sulfate	122,000 tons

Venezuela

16.14 The total value of chemicals' output almost doubled from £43M to £80M between 1960 and 1965. Total output is planned to reach £125M in 1968.

16.15 The following investments were planned for the period 1965–8:

	£M in 1964 *prices*
Fertilizers	£36M
Sulphuric acid	5
Explosives	6
Synthetic rubber	10
Aluminium sulfate	3
Polyvinylchloride	6
Polyethylene	11
Dodecylbenzol	2
Basic petrochemicals	34
Ammonia	10
Other chemicals	10

CHAPTER 17

Foreign demand: India, Pakistan and Japan

India

17.1 The most important sector of India's chemical industry is fertilizers. The production of fertilizers developed as follows between 1960–1 and 1964–5, compared to the country's estimated requirements in 1970–1:

(Metric tons)

	Production			Requirements
	1960–61	1962–63	1965–66	1970–71
Nitrogen fertilizers (N)	110,040	193,000	245,000	2,000,000
Phosphate fertilizers (P_2O_5)	55,000	70,000	130,000	700,000
Potassium fertilizers (K)	negligible	negligible	negligible	320,000

Source: FAO, Rome

17.2 In addition, the following indications of installed capacity (1966) and the echeloning of arrival on stream of new capacity show the massive investment intended in this sector. There have been delays in the Indian chemical industry realization, so that figures should be written down somewhat. Alternatively, a five year phase-lag in execution of the planned requirements may be assumed.

17.3 Fertilizer production capacities in India are planned as follows:

(Metric tons)

	Nitrogen	Phosphate
End 1966	682,300	286,800
Projects due for completion in 1967–68	213,000	132,100
Projects due for completion in 1969–71	1,316,000	330,000
Projects envisaged for completion in 1970–71	646,000	—
Projected total capacity end 1971	2,857,300	748,900

Source: United Nations Ind. Development Organisation, October 1967

17.4 The world's largest fertilizer complex will be installed in India, in Gujarat State. The total cost of the project is estimated at £96M. The complex, due for completion by 1974–5, is hoped to produce ultimately 2·3 million tons of fertilizer material, containing 1·2 million tons of balanced plant nutrients.

17.5 India is installing a number of ammonia, ammonium sulphate, sulphuric acid, phosphoric acid, etc. plants, with capacities between 170 and 500 tons per day. Most plant equipment is imported, Japan having a significant share in the market.

17.6 Financial and sometimes political problems however often hinder the implementation of announced investment plans.

Pakistan

17.7 Total output of the chemical industry rose from £7·2M in 1960 to £25·0M in 1965. About 50% of output in 1965 was linked to pharmaceutical production.

17.8 According to plans for 1970 and 1980, the industry's capacity will grow considerably.

17.9 The following capacities are being installed (end 1966–end 1968):

Product	Capacity tons/year	Remarks
Concentrated superphosphate	390,000	
Ammonia	180,000	Investment £26M
Other ammonia	400,000	
Urea	173,000	Investment £11M
Other urea	182,000	
Urea-fertilizer	173,000	Investment £9M
Ammonium nitrate	130,000	Built by French ENSA

17.10 The longer term situation is illustrated by the following table; giving development of production and capacities of some leading chemicals in Pakistan:

Product	Production, tons		Capacity tons/year		
	1960	1965	1965	1970	1980
Sulphuric acid	1,344	20,280	30,000	95,000	160,000
Chlorine	—	4,400	—	35,000	55,000
Caustic soda	6,000	11,280	—	37,400	58,700
Soda	27,000	32,000	32,000	150,000	—
Ammoniumnitrate	—	72,000	103,000	—	—
Ammoniumsulfate	45,430	45,000	50,000	160,000	275,000
Urea	—	130,000	176,000	310,000	770,000

Source: Chemische Industrie and other sources

Japan

17.11 Practically the whole of Japanese exports of pressure vessels is handled by contracting companies, either on the basis of contracts between the final user, the engineering company and the pressure vessel builder, or through the fully-owned engineering subsidiaries of the leading pressure vessel fabricators. It is estimated that this latter pattern is of overwhelming importance. Indeed, practically all the large pressure vessel fabricators—whose share in the market for pressure vessel exports amounts to at least 75%—have engineering subsidiary companies or specialised chemical plant contracting divisions.

17.12 As to the domestic market, the role of contractors, although less important than for exports, is still significant. A considerable portion of the home market for pressure vessels is captive: many of the leading pressure vessel fabricators belong to groups who either fully own chemical and petrochemical companies or have, in the framework of the national industry's expanded financial integration, interest in chemicals and petrochemicals.

Table 17(1)

Evolution of equipment investment in the main pressure vessel user sectors (£M)

	1960	1961	1962	1963	1964	1965	1966	1972
Petrochemicals and refinery	£39M	73	62	75	93	123	150	370
Organic and pharmaceuticals	52	74	69	70	111	97	105	210
Inorganic and fertilizers	84	95	88	85	106	110	112	143
TOTAL CHEMICAL INDUSTRY	175	242	219	230	310	330	367	723

Source: Bank of Japan; Ministry of International Trade and Industry

17.13 The investment data in Table 17(1) are indicated in the Japanese sources as equipment investment. It has been calculated that they make up for 65% to 75% of the total annual investment expenditure in the chemical, petrochemical and refinery industries on a basis of hardware acquired *and* erected. The figures would, on the other hand, only represent about 50% of total annual investment if the figures refer specifically to equipment investment (eg hardware acquired).

17.14 Investment in equipment in 1972 has been calculated on the following assumptions:

general economic growth of 8% per year between 1966 and 1972 (a net growth target of 8% per year has been set up by the Japanese government);

the output of petrochemicals will increase 20 to 25% per year (40% during the period 1960–63);

the production of organic chemicals will grow by 15% per year (20% in 1963–4);

the growth of inorganics and fertilizers will slow down to 5% per year.

17.15 The demand for investment equipment in petrochemicals could grow even faster, as technological innovation is the fastest in this sector. This may result in greater replacement demand stemming from the accelerated economic (and technical) obsolescence of production facilities.

17.16 No indication could be obtained from Japanese sources concerning the possible vessel content of equipment investment in the industry, although if one applies a British vessel to plant and machinery ratio, one arrives at the figures in Table 17(2).

TABLE 17(2)

Japanese domestic demand for vessels (£M)

(1962–1966: estimate 1972)

Sector	1962	1963	1964	1965	1966	1972
Petrochemicals and refinery	£6·9M	9·0	11·2	14·8	18·0	44·4
Organic and pharmaceuticals	8·3	8·4	13·3	11·6	12·6	25·2
Inorganic and fertilizers	10·5	10·2	12·7	13·2	13·4	17·2
TOTAL	25·7	27·6	37·2	39·6	44·0	86·8

Source: Application of a percentage of 12% in respect of the vessel in plant and machinery content as in Table 17(1)

CHAPTER 18

Comparison of UK and foreign pressure vessel industries

18.1 The major similarities and differences between the UK and European industries are indicated, first on an industry basis and then by comparing some of the leading companies of each country. The information on the foreign industries has been derived by desk-work and by visits to France, Italy, Germany, Sweden and Japan. These visits were made to pressure vessel fabricators, associations, contractors and final users.

The similarities

18.2 The many similarities between the pressure vessel industries of different countries should not be overlooked. For example, although some foreign countries have some very large specialist and integrated pressure vessel manufacturers, there are always present in each country a larger number of smaller, less specialised builders as in the UK. The one exception to this seems to be Japan where about forty fabricators are to be found, all of whom are large companies and in some way integrated. When compared with these large companies the output of smaller companies is of little market significance.

18.3 Other similarities between industries include the production facilities. In particular, cranage, forming, welding and machining equipment do not vary significantly when an overall comparison of industries is made. However, a handful of foreign companies stand out as being able to work in very high tonnages and thicknesses, eg Chantier d'Atlantique, Rheinstahl, and Japan Steel Works. All these companies have activities outside pressure vessel manufacture.

18.4 Finally the similarity between market conditions, at least in European countries, should be mentioned. The domestic markets for pressure vessels is cyclic in all the countries although perhaps less so than in the past five years in the United Kingdom. For example, the German pressure vessel industry became underloaded in 1967 in much the same way as the British industry.

The differences

Structural differences

18.5 While the bulk of the industries in all countries (except Japan) are similar, the structural differences between the leading companies in each country are significant. These differences largely relate to the degree of integration. This factor for Japan and Germany is highly significant and remains significant to a lesser extent for Sweden, France and Italy. Integration of these foreign pressure vessel manufacturers is mainly with a steel producing interest and to a much lesser extent with final users such as chemical and petrochemical companies. The latter is of significance only in Japan. The form of integration may simply be financial but sometimes involves large production units for steel alongside fabrication facilities. The most important effects of the financial links are:

in times of low demand, price cutting can be absorbed throughout the group;

the captive market in the case of groups with chemical interests can be used as a buffer against external market variations.

18.6 Another and more frequent form of integration to be found, particularly in Japan and to a lesser extent in European countries, but in all cases more than in the UK, is a link with an engineering contractor, through whom the hardware in the form of part of a complete process plant can be sold. Again the integration can be purely financial or organisational, in the form of wholly-owned contracting subsidiaries.

Management

18.7 Although the number of interviews with fabricators in the foreign countries was not large, an impression was formed of a high calibre of management. Directors were found to have both a technical and commercial competence and their policies towards personnel, production and sales were both knowledgeable and positive. The understanding of market conditions seemed again to be good, which is perhaps one explanation for the high export factors in pressure vessels.

Labour

18.8 The major difference between the UK and foreign industries with regard to labour is that demarcation presents no problems in the foreign countries. In fact, the British position on inter-craft and inter-union disputes, and the existence of 'mates' is quite unique and incomprehensible to those not brought up with the British 'system'.

Raw materials supply

18.9 Whilst British fabricators expressed considerable dissatisfaction with the quality, delivery and service of steel supplies from home production, such criticism was very rarely met in interviews with foreign pressure vessel fabricators. Again in contrast to the UK no criticism was encountered about forged components.

18.10 Steel prices as published did not show any significant variations, but the extent to which the 'official' price (especially in the European Coal and Steel Community member countries) was applied in each country was uncertain. It seems that the normal policy was to grant the 'export' steel prices to vessels built for export, but over and above this advantage not enjoyed by British fabricators, there seemed to be some 'flexibility' in pricing steel in each country according to market conditions.

Design standards and inspection

18.11 In general the situation on design and construction standards as well as inspection is no better in foreign countries than in the UK with the exception of the Federal Republic of Germany. In particular the German standard encourages the use of advanced steel, and modifications are easier to introduce. There was no undue duplication of inspection, and inspectors were said to be co-operative with respect to arranging inspection to fit in with production schedules.

18.12 It also seemed that a more flexible approach to the use of foreign standards could be found at company level in most foreign countries. In some cases, such as France, the reason arose through the lack of a clear and complete national standard. In some ways France may be considered the opposite of Germany with regard to the system of standards and inspection.

Governmental policy and interventions

18.13 Government policy towards the pressure vessel industry in the countries under discussion is in some cases rather as in the UK; for example, in France, Sweden and Germany government interest is slight, and is mainly directed towards the facilitating of export of industrial plant and equipment. Italy is slightly different in that the State owns the largest individual producers of pressure vessels and some other companies are involved to a greater or lesser extent with groups backed or controlled by the Government. Direct and other subsidies to assist the export of pressure vessels in Italy are considerable as the costs involved in exporting at prices low enough to be called 'dumping' can be absorbed throughout the steel producing and fabricating complex, and though it is virtually impossible to prove in full, various government measures have probably helped to ease the individual Italian fabricating companies through a difficult period in the domestic markets.

18.14 Japan also has a very particular state: industry relationship. Its main aspect is that government credit is offered at low and differential interest rates and that the government grants fiscal advantages for investment in selected sectors. Government control in Japan is very considerable, without actual 'state ownership'. For example, state direction of research is extensive.

Tabular comparisons

18.15 Table 18(1) provides a comparison of pressure vessel industries of the UK, Germany, Japan, France, Italy and Sweden, in the three areas: structure of industry, demand, and export/import trade. The data is self-explanatory. It should be stressed that the figures given are estimates based on what information there was available at the time the comparison was compiled, and the figures serve at best as an approximate guide only. Since the data on foreign countries has been based on official and professional statistics, it has not been possible to distinguish between shop-built and site-built output. It is believed that a proportion of the site-built output may come within the total official output figures. To enable a reasonable comparison to be made between the foreign industries and the UK industry (for which shop-built *and* site-built outputs have been ascertained), the UK output figure used in the comparative Table 18(1) has been obtained by adding half of the site-built output (ie half of £16M) to the total shop-built output (ie all of £57·7M), to obtain an 'equivalent figure' of £65·7M.

18.16 Table 18(2) provides an international comparison of ten leading pressure vessel fabricators from the six countries.

TABLE 18(1)

International comparison of pressure vessel industries for 1966

(Approximate data only)

	STRUCTURE OF INDUSTRY				DEMAND		EXPORT/IMPORT TRADE				
	(a) Total output	(b) No. of companies estimated as making half output in (a)	(c)= a/2b Annual output of average company in column (b)	(d) *Annual* % increase in output	(e) *Annual* % increase in equipment investment	(f) Estimate of *annual* % increase in domestic demand	(g) Gross exports (approximate)	(h)= 100g/a Gross exports as % of output	(i) Gross imports (approximate)	(j)= (g−i) Nett trade balance (approximate)	(k) *Annual* % increase in exports
Data for period:	1966	1966	1966	1964–66	1964–66	1966–72	1966	1966	1966	1966	1964–66
Units:(1)	£M	No.	£M	%	%	%	£M	%	£M	£M	%
F.R. Germany	70	15—20	1·7—2·3	+8	+12	+8	17	24	1·7	+15	+8
Japan	60±5	4—9	3·8—8·1	+1	+13	+12	20	30	0	+20	+100
United Kingdom	66(1)	21	1·5	+30(2)	+20(3)	−4(3)	8	16	9·5	−1·5	0(6)
France	40	10—15	1·3—2·0	+3	+12	+5	—	—	—	−(5)	—
Italy	18	5—10	0·9—1·8	−9	+4(4)	+5	3—5	17—32	0·7	+2·3—4·8	+40
Sweden	4	1—2	1—2	+2	+20	—	0·3	9	0·2	+0·1	−27

Notes: (1) £M for all countries is in pre-devaluation £ (i.e. $2·80 to the £1). All data refer to pressure vessels, heat exchangers and tanks. In data for foreign countries it was not possible to distinguish between shop-built and site-built output, and a proportion of site-built output probably comes within the total output figures. To enable a reasonable comparison to be made the UK output data in column (a) of £66M has been obtained by adding all shop output (£58M) to half of site output (£16M)

(2) Based on orders received by 18 companies representing 30% of pressure vessel output; this result is not statistically significant but it is believed to be reasonably representative of the trend during 1964–66

(3) UK demand estimates based on the four major sectors; chemicals, gas, oil refining, and electricity generation

(4) For 1963–64 the figure is −15%

(5) France is a nett exporter of heat exchangers (£5M were exported from a total production of £10M in 1966)

(6) This figure is for direct exports during 1964–66 (i.e. not via contractors); in contrast the direct exports during 1962–64 doubled in value

(d), (e), (k)—These columns are based on smoothed curves wherever a historic series of data exists

TABLE 18(2)
International comparison of leading pressure vessel fabricators

	Capital employed	No. of employees	Financial links with contractors	Financial links with steel production	Overseas sales organisation	Total output of heavy fabrication	Total output of PVs, H E and tanks	Total area of shops (sq. ft.)	Max. wt. of shop built vessels (tons)	Max cranage (tons)	Site building activity	R & D activity
Firm A UK	£4·5M	3,000	Contracting division	None	Own overseas subsidiary	£10M	£1·2M	163,000	200	100	£3M	medium
Firm B UK	—	1,100	Small engineering subsidiary	None	Overseas offices	£2·5M	£2·2M	134,000	120	120	£0·1M	medium
Firm C F.R. Germany	£3·0M	4,600	Contracting division	Same group	Contracting division subsidiary	£15M	£2·5M	190,000	175	150	—	high
Firm D France	£18·5M	15,100	Group's contracting subsidiary	Same group	Contracting subsidiary	£30M	£4·0M	—	500	300	—	high
Firm E France	£2·8M	1,100	—	None	—	£14M	£6·0M	—	200	100	—	medium
Firm F Italy	Issued £0·6M	450	None	—	Agencies in European countries	£4·5M	£4·0M	12,000	150	80	significant	medium
Firm G Italy	£0·3M	750	None	None	Agents in Europe and U.S.A.	£3·4M	£3·5M	—	220	100	—	low
Firm H Sweden	Group £17M	Heavy fabrication 2,200	Group's contracting subsidiary	Same Group	Group's subsidiaries	Group turnover £65M	£2·5M	236,000	250	240	considerable	high
Firm I Japan	£50M	60,000	Own subsidiary	Same Group	Group subsidiaries	Group turnover £280M	—	—	600	—	considerable	high
Firm J Japan	£3·0M	2,300	Own division	—	Own agencies	—	—	—	550	300	significant	high

Source: Companies and Professional Associations

CHAPTER 19

Future world demand for vessels by type

19.1 The present economic survey provides a reasonable outline for the current (1967) and future (1972, 1977) demand for vessels, on the basis of estimates of the *overall* financial investment in vessels of all types and sizes during the selected years. The survey also provides adequate details of the structure of the present pressure vessel industry (as at 1966).

19.2 The economic survey thus goes far in providing information and forecasts on demand for vessels in 1977 and thereby the *overall* capacity of the UK pressure vessel industry required in 1977, but it does not breakdown the industrial capacity required in 1977 according to type or size of vessels required. Because of this it is not possible to make any specific recommendations as to the *types* of fabrication capacity or expertise required in 1977 in terms of maximum sizes of vessel or types and thicknesses of materials required. It is therefore not feasible to estimate what the industry should look like in 1977 from a technical and production ability viewpoint, so as to best meet the vessel demand in 1977.

19.3 It would therefore appear to be desirable to implement a techno-economic assessment of the future demand for vessels by type and size. A further result of an assessment of this nature would be an indication of the likely structure of the pressure vessel industry required in the future, regarding the production capabilities of individual companies in terms of pressure vessel materials, type and size. However, forecasting demand for process plant is particularly difficult and requires continuous efforts from inter-disciplinary teams to develop and improve techniques, and to revise existing forecasts in the light of economic developments and technological change.

19.4 There is little doubt that such a techno-economic study would be very useful for fabricators in indicating the likely types and sizes of vessels required in the future. However, the route necessary to arrive at estimates of vessel types and sizes in the future involves the estimation of the likely sizes and types of process plant required in the future, particularly chemical plant and oil refinery plant.

19.5 It would therefore appear desirable to consider the problem at the process plant level rather than at the vessel level, as vessels are but one of the many types of items making a complete process plant. Such an approach would need to forecast the likely growth in demand for the major products of the chemical and oil industries. This forecast could then be used, bearing in mind any probable technological changes, to predict the likely demand for chemical process and oil refinery plant in the future. Thus estimates of the likely production and technical requirements could be obtained for all components of process plant (e.g. pumps, pipes, valves etc.) as well as for vessels. This would appear to be the best approach as the main unit of extrapolation (to obtain the future estimates for *hardware*) would be the individual process plant.

Suggested outline for a techno-economic survey

19.6 Steps necessary to carry out such a survey are suggested here. These are put forward as suggestions only and before any survey could be initiated it would be necessary to develop detailed proposals defining the relevant objectives, scope, methods and costs of such a survey, including its duration.

19.7 The survey involves the development of the future market demand forecasts for 1977 for the types of vessels likely to be required in terms of materials, thicknesses, sizes etc. as well as quantities required. Such a forecast could be derived as a function of the likely development of the types of processes (allowing for technical change) required to supply future estimated demand for chemical feedstocks, oils, gases, etc. Consideration, for simplicity, could be limited to the three main vessel user sectors (heavy organics, oils, gas) which represent *at the present time* 80% of demand. A brief review could also be made as to whether any new large user sector would emerge by 1977 (e.g. explosive growth in small 'packaged' nuclear power plants).

19.8 A critical part of the study could be the technical assessment of the *scale* of individual plants required to produce all (or part) of the differences in the production capacities as between 1977 and 1966. This should be accompanied by a technical assessment of the types of vessel required for these plants which, when summed over the different final user sectors, should indicate the overall demand for vessels by type in 1977. From the overall demand for vessels by type in 1977 it should be possible to deduce the UK vessel industrial capacity required to produce these vessels. In order to obtain an indication of the likely effect on the 1977 pressure vessel industry of an alteration in the estimated future demand in the three main user sectors (due to a change in the demand pattern for chemicals, oils, and gas), estimates may also be prepared to indicate the effect of possible margins of error in the analysis.

19.9 The various steps necessary to determine the likely pattern of future demand for vessels by type is indicated in a schematic diagram in Fig. 19(1). Other components of process plant may be dealt with in a similar manner. In the diagram the letter (S) denotes assessment by sector (eg separately for chemicals, oils and gas) while the letter (T) denotes assessment by the total of all three sectors. The data in any block linked by a solid line requires to be known or estimated in order to arrive at the final result. The data in blocks linked only by dashed lines need not be known to obtain the final result; but could be obtained as a further check on the procedure if thought necessary. The likely pattern of imports and exports would also need to be taken into account.

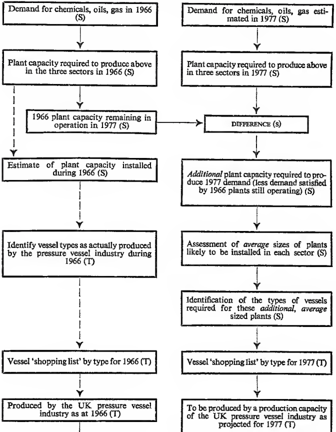

Demand for chemicals, oils, gas in 1966 (S)
Demand for chemicals, oils, gas estimated in 1977 (S)
Plant capacity required to produce above in the three sectors in 1966 (S)
Plant capacity required to produce above in three sectors in 1977 (S)
1966 plant capacity remaining in operation in 1977 (S)
DIFFERENCE (S)
Estimate of plant capacity installed during 1966 (S)
Additional plant capacity required to produce 1977 demand (less demand satisfied by 1966 plants still operating) (S)
Identify vessel types as actually produced by the pressure vessel industry during 1966 (T)
Assessment of *average* sizes of plants likely to be installed in each sector (S)
Identification of the types of vessels required for these *additional, average* sized plants (S)
Vessel 'shopping list' by type for 1966 (T)
Vessel 'shopping list' by type for 1977 (T)
Produced by the UK pressure vessel industry as at 1966 (T)
To be produced by a production capacity of the UK pressure vessel industry as projected for 1977 (T)
DIFFERENCE (T)
Modifications required by the present UK pressure vessel industry so as best to produce the likely pattern of vessel demands in 1977 (T)
UNKNOWN AND FINAL OBJECTIVE

FIG. 19(1). Schematic diagram for estimation of the likely future demand pattern for vessels

CHAPTER 20

Summary

Pressure vessel fabricators

20.1 The future progress of the industry is basically in the hands of its top management. The steps that could be taken by managements include the following:

(1) attention could be given to any factors that may contribute to less efficient use of heavy fabrication shops. Towards this goal the management of each fabrication shop could:

(a) consider modification in the lay-out of each shop to follow the optimum sequence of the fabrication process;

(b) consider the introduction of an adequate cost control and production planning system where these were not already present, to allow accurate estimates to be made for tendering purposes and to enable delivery to be met;

(c) consider an analysis, based on equipment already installed, of the most suitable product specialisation which the company could develop. This could be cross-checked by market research to ensure that the product specialisation corresponds to a need on the market;

(d) consider direct negotiation with local representatives of unions to attempt to remove any demarcation practice present in the shop;

(e) encourage the entry of a younger element with the requisite engineering and commercial skills into the management and to assume responsible positions in engineering and sales.

(2) more effort could be devoted towards improving the *marketing* of products. Thus the management of each fabricator could:

(a) consider the market research of trends in the process uses of pressure vessels to identify future product opportunities;

(b) prepare adequate publicity brochures setting out the equipment installed, the shop size, the product specialisation and any particular skills;

(c) sell pressure vessels overseas by contact with both British based contractors and foreign contractors and final users. (This implies considerable overseas travel together with the appointment of engineering sales agents in chosen foreign countries. Consideration could be given for cost reasons towards the creation of overseas offices in conjunction with other British fabricators with complementary products. Success in overseas selling, given parity in price and delivery, is largely achieved by well organised and sustained effort);

(3) higher technological innovation could be encouraged, particularly on design and development of materials and manufacturing techniques;

(4) the development of unit operations in which pressure vessels could be incorporated, as a means of selling mechanical engineering expertise, could be considered. This implies the development of chemical engineering and contracting expertise and is directed towards the larger fabricators;

(5) the initiation of a working agreement on design and sales with one or more foreign contractors. (Some successful examples of this policy—eg between American contractors and Japanese fabricators—were encountered in the survey);

(6) the consideration of the possibility of a negotiated rationalisation of production facilities between existing pressure vessel fabricators, possibly on a regional basis. (There exist many channels—both governmental and private—by which negotiated mergers could be arranged, and the relevant Trade Association could also provide a valuable intermediary for negotiation).

Trade unions

20.2 Security of employment for Union members working in the pressure vessel industry is dependent upon the economic health and competitiveness of this industry in an international context. The responsible officers of the relevant trade unions could co-operate in considering any initiative from managements in the industry towards the introduction of labour flexibility systems, together with the acceptance of non-apprentice trained personnel for skilled trades.

Pressure vessel fabricators and their trade associations

20.3 Further improvements in competitiveness of British pressure vessel fabricators may be brought about by joint action and collaboration between fabricators. This may be helped through common membership of a single trade association. Such an association could be representative of the industry, and the measures it introduced would be likely to have quick results. A suitable trade association already exists (the Tank & Industrial Plant Association (TIPA)) and the following steps could be taken by TIPA:

(1) the acquisition of a more complete membership so that it embraced all significant pressure vessel manufacturers in the United Kingdom;

(2) the development of a definitive description of the British pressure vessel industry, for example by the production of a *UK Pressure Vessel, Tank and Heat Exchanger Manufacturers' Manual*, in which individual members could define clearly their capabilities and product specialisation, this would provide a valuable sales tool in home and export markets;

(3) the setting up of a market intelligence and technical service (which might be funded by a special subscription of those members who wished to support it). This service could provide reports on both home and export market opportunities, an appreciation of process changes and their impact on pressure vessel requirements;

(4) the continuation and enlargement of its present statistical records.

Chemical contractors and final users

20.4 Pressure vessel purchasing techniques play a crucial role in the development of pressure vessel industries. Steps that contractors and final users could take include:

(1) awareness of the effort put in by technologically strong companies in terms of research, development, design and past performance even where this effort may not be reflected in lower prices for given vessels;

(2) the limitation of the number of quotations sought from fabricators for each pressure vessel of simple design and materials;

(3) the purchase of other vessels (of high technological input) by limited tender and direct negotiation;

(4) the maintenance of adequate aggregated records of the main items of chemical plant procured on a year by year basis for provision when necessary to official bodies;

(5) consideration of the use of the trade association as the central body for statistics on both investment in equipment and total investment.

Government

20.5 The British Government can influence the pressure vessel market in various ways, of which the following are examples:

(1) through action when reasonable evidence of dumping of pressure vessels in the UK is presented, bearing in mind that the compilation of evidence for a jobbing fabricated product is very difficult;

(2) the encouragement of contractors and final users to obtain from foreign suppliers a cost breakdown between raw materials, labour, overheads and profit when dumping is suspected;

(3) through ensuring that the UK plays a leading role in international standardization and that false 'technical' barriers cannot operate against free international trading;

(4) through recommending the British Steel Corporation to reconsider steel pricing policy;

(5) the provision of adequate statistical data particularly from contractors and final users;

(6) through enquiring into problems of the forging industry in the United Kingdom.

British Standards

20.6 Much of the technological strength of the industry depends on the quality of the standards available for pressure vessel design and related subjects. Furthermore, several criticisms by the British pressure vessel industry with regard to standards might be eliminated by action relating to these standards. Such measures might include:

(1) provision of a larger permanent staff to enable quicker work in producing and modifying standards;

(2) the discontinuation of BS 1500 in favour of an enlarged BS 1515 (which should replace its UTS requirement in the calculation of design stress by a YS based criterion);

(3) increasing the effort on standards relating to pressure vessels, for example those for steel plate and forgings.

ANNEX A

Cost breakdown of pressure vessel tenders offered by several UK fabricators

1. The following tables show the final costs and the cost breakdowns for two high quality low carbon mild steel gas storage vessels (Vessels A and B), and two other mild steel vessels, as supplied by UK tendering companies. The total tender prices are listed together with the component costs.

2. It may be seen that there are very considerable variations in both the component costs and in the total prices. These may partially be explained by differences in definition used by the various companies, ie 'Direct labour' may or may not include the cost of site erection; also the cost of dished ends may or may not be included in 'materials', dependent upon whether they were bought in or not.

3. A further analysis has been done by obtaining mean values for component costs by using only those tenders for which entries were made in all five component cost columns. Using these mean values the component costs have been derived as percentages of the mean total vessel cost. This is shown in Table A(5), where it is evident that for a storage pressure vessel costing about £30,000: materials account for about 40% of the total cost; direct labour accounts for 10%; overheads, profit and contingency account for about 30%; and transport and site work less than 20%. However, for a small mild steel vessel costing about £5,000, whilst the materials and labour costs remain at a little over 40% and 10% respectively, the overheads, profit and contingency account for 40% and transport and site work less than 5%. The cheaper transport and site work of the smaller, lighter vessel is not unexpected.

4. A measure of the wide scatter of the companies' estimates is given by the ratios of maximum component costs. These are also shown in Table A(5). These ratios are 1·7 and 1·5 for total vessel costs for the two large vessels A and B; this represents a scatter of about ±30% about the mean total costs. There is rather greater variation in how the total costs are divided into the component costs. For example, overheads for Vessel A vary so much that one company's estimate was 4·8 times as large as that by another company (for the same vessel). It may be concluded that the companies used different methods for deriving their quotation prices; and it is also very likely that different definitions were used for the five major component cost headings.

5. It is suggested that TIPA might encourage the development of standard cost accounting methods as well as standard definitions for the various component costs that make up the total quotation price of a vessel. Unless individual companies in the industry appreciate how to break down the total cost of a vessel more rigorously into its component costs, it is difficult to see how cost reduction techniques (eg cost-effectiveness analysis) may be applied so as to increase further the competitiveness of the industry.

TABLE A(1) Vessel A

Tender	Materials (including consumables)	Direct labour	Overheads	Profit and contingency	Transport and sitework	Total per vessel
1	£10,448	4,101	8,202	3,089	4,471	30,311
2	11,370	2,378	6,505	985		21,238
3	12,875	2,685	10,028	4,923	3,838	34,349
4	14,200	3,675	14,975	3,650		36,500
5	11,170	6,368	5,670	1,050	2,899	27,157
6	13,930	2,538	9,514	nil		25,982
7	13,861	3,642	7,334	579	8,634	34,050
8	11,376	1,741	5,881	2,614	3,699	25,311
9	10,515	4,712	8,227	3,947	3,875	31,276
10	18,332	2,180	4,708	2,281		27,501
11	12,168	1,491	6,699	2,343	6,316	29,017
12	23,222	5,960	3,091	nil		32,273
13	12,858	1,908	8,015	2,135	9,033	33,949
Mean values for tenders: 1, 3, 5, 7–9, 11, 13	£11,909	3,331	7,507	2,585	5,345	30,677
Component costs as % of total mean cost	39%	11%	25%	8%	17%	100%
Minimum component costs (1—>13)	£10,448	1,491	3,091	nil	omitted	21,238
Maximum component costs (1—>13)	£23,222	6,368	14,975	4,923	9,033	36,500
Ratio $\left(\frac{\text{max}}{\text{min}}\right)$ costs	2·2	4·3	4·8	∞	∞	1·7

TABLE A(2) Vessel B

Tender	Materials (including consumables)	Direct labour	Overheads	Profit and contingency	Transport and sitework	Total per vessel
1	£14,977	2,409	6,023	2,341		25,750
2	13,937	1,668	4,895	nil	3,198	23,698
3	14,454	3,628	6,764	498	5,716	31,060
4	13,030	1,800	6,720	3,297	7,820	32,667
5	11,303	4,399	7,896	1,007	3,179	27,784
6	16,201	1,743	4,337	2,229		24,510
7	12,442	1,340	6,253	394	4,245	24,674
8	21,367	8,238	4,305	1,090		35,000
9	13,633	1,711	6,983	2,483	5,359	30,169
Mean values for tenders: 2–5, 7, 9	£13,133	2,424	6,585	1,275	4,919	28,342
Component costs as % of total mean cost	46%	9%	23%	5%	17%	100%
Minimum component costs (1–>9)	£11,303	1,340	4,305	nil	omitted	23,698
Maximum component costs (1–>9)	£21,367	8,238	7,896	3,297	7,820	35,000
Ratio $\left(\frac{\text{max}}{\text{min}}\right)$ costs	1·9	6·1	1·8	∞	∞	1·5

TABLE A(3) Vessel C

Tender	Materials (including consumables)	Direct labour	Overheads	Profit and contingency	Transport and sitework	Total per vessel
1	£1,473	668	1,762	nil	352	4,255
2	1,924	424	922	160		3,430
3	1,894	433	1,273	nil		3,600
4	2,213	482	1,670	nil	38	4,403
5	1,620	400	1,010	333	262	3,625
Mean values for tenders: 1, 4, 5	£1,768	516	1,480	111	217	4,094
Component costs as % of total mean cost	43%	13%	36%	3%	5%	100%
Minimum component costs (1–>5)	£1,473	400	922	nil	omitted	3,430
Maximum component costs (1–>5)	£2,213	668	1,762	333	325	4,403
Ratio $\left(\frac{\text{max}}{\text{min}}\right)$ costs	1·5	1·7	1·9	∞	∞	1·3

TABLE A(4) Vessel D

Tender	Materials (including consumables)	Direct labour	Overheads	Profit and contingency	Transport and sitework	Total per vessel
1	£2,170	678	2,315	nil	388	5,551
2	1,855	310	626	279		3,070
3	1,759	513	1,473	nil		3,745
4	2,542	456	1,789	447	55	5,289
Mean values for tenders: 1, 4	£2,356	567	2,052	223	221	5,420
Component costs as % of total mean cost	44%	10%	38%	4%	4%	100%
Minimum component costs (1–>4)	£1,759	310	626	nil	omitted	3,070
Maximum component costs (1–>4)	£2,542	678	2,315	447	338	5,551
Ratio $\left(\frac{\text{max}}{\text{min}}\right)$ costs	1·5	2·2	3·7	∞	∞	1·8

TABLE A(5) Summary for vessels A, B, C, D

Vessel	No. of Tenders	Mean price	Component Costs (%)					Ratios of Max. to Min. values of component costs						
			Materials	Direct labour	Over-heads	Profit and contingency	Transport and site-work	Materials	Direct labour	Over-heads	Profit and contingency	Transport and site-work	Total vessel cost
		(£)	(%)	(%)	(%)	(%)	(%)						
A	13	30,677	39	11	25	8	17	2·2	4·3	4·8	∞	∞	1·7
B	9	28,342	46	9	23	5	17	1·9	6·1	1·8	∞	∞	1·5
C	5	4,094	43	13	36	3	5	1·5	1·7	1·9	∞	∞	1·3
D	4	5,420	44	10	38	4	4	1·5	2·2	3·7	∞	∞	1·8

ANNEX B

Analysis of pressure vessel fabricating companies in the UK

Introduction

1. The analysis of the pilot and revised long questionnaires of the economic survey has been confined to the 27 companies returning these who were in shopbuilt pressure vessel output categories 3, 4 or 5 (shop output of pressure vessels in 1966 of £200,000 or more). Although there were 35 companies in these three output groups, 8 of these companies returned short questionnaires so no detailed information about them is available.

2. The 27 companies analysed included all 11 in output groups 4 and 5, and 16 of the 24 companies in group 3. It is estimated that the 27 companies together accounted for approximately 60% of shop pressure vessel output in 1966. Unfortunately, some of the 27 returns were incomplete and several particular analyses may therefore relate to fewer companies. The total numbers of companies contributing to such analyses are indicated in the text or tables.

Factors relating to capacity

3. The companies were asked if they were fully loaded in 1966 or had spare capacity. Those companies whose shops were fully loaded were also asked to give their production limitations in 1966. Twenty-three of the 27 companies were fully loaded, the most important limitations on output being shortage of skilled labour (mentioned in almost every case) and production floor space (mentioned by nearly half of the companies). Delays in receiving materials also featured as important obstacles to higher output.

	Production limitations	*Number of companies (total=23)*
Skilled labour	Availability	20
	Reluctance to go to another shift	4
Floor space	Production	10
	Storage	2
Material supplies	Steel plate	2
	Forged parts	6
	Dished ends	5
	Other	—
Plant and equipment	Materials handling and cranage capacity	3
	Fabricating equipment	—
Other factors		—

Use of skilled labour

4. Most of the companies worked a day shift or a day shift with a small night shift only. The interviewing programme provided ample evidence of the great difficulty in

persuading men to work a full double-shift system, particularly in areas with full employment. Even the small night shift for key operations presented problems in regard to staffing (particularly the quality of the supervision) and to the sharing of jobs between men on different shifts (where piece-rate payment systems were used this could lead to difficulties in calculating the amount due to each man concerned).

Shift system worked, June 1966	*Number of companies*
Day shift only	6
Double day shift	—
Day and small night shift	13
Day and full night shift	1
Other* (2 shifts)	5
TOTAL	25

*The pilot questionnaire simply asked the number of shifts worked: 5 companies said 2.

5. The interviews also revealed a tendency for companies to work long hours. In many areas a certain proportion of overtime was regarded as a normal part of the working week, and some men would leave a company if they could not obtain any overtime.

Average working week for welders and platers, June 1966

Hours	*Number of companies*
39–44	4
45–50	18
51–56	4
TOTAL	26

Some companies had succeeded in reducing overtime as a result of introducing work study and incentive payment schemes.

Production control

6. Since the industry's customers had complained of weaknesses in its production control, data is given to show the ratio of technical production staff (working mainly or wholly on pressure vessels) to workers in the heavy fabrication shop [Table B(1)]. It should be noted that the detailed analysis of the industry's output (given in Chapter 3) showed that while pressure vessels accounted for a high proportion of total shop output for the companies with a vessel output of over £500,000, this was not so for the companies with a smaller vessel output. For companies with a vessel output of £200,000–£500,000, therefore, Table B(1) may understate the number of production staff for the whole fabrication shop.

7. About half the companies giving the relevant information gave a ratio of 1 technical production man to every 10 to 15 production workers. Several companies, however, had considerably greater ratios than this; one technical man to every 30 to 40 workers or even more.

TABLE B(1)
Production control by technical employees

		(a)	(b)	(a+b)
Company category: Shop-built pressure vessel output, 1966		£200,000 to £500,000 (12 companies)	£500,000+ (9 companies)	£200,000+ (21 companies)
Number of workers in heavy fabrication shop	Minimum	65	113	65
	Average	177	447	293
	Maximum	495	917	917
Number of heavy fabrication shop workers to *one production* technical employee*	Minimum	10	4·1	4·1
	Average	24	38 (20**)	30 (23**)
	Maximum	65	177	177
Number of all direct production workers to *one production* technical employee*	Minimum	8	2·3	2·3
	Average	21	34 (17**)	27 (20**)
	Maximum	59	167	167

* Working wholly or mainly on pressure vessels

** Averages drop to half the overall values if the overall maximum figure (for *one* company) is neglected

Comparison of company activity, 1966 *and* 1967

8. Companies were asked to provide two indicators of their level of activity in June, 1967, compared with June 1966: the average number of platers and welders employed and their average working week. Table B(2) shows a tendency for both to drop but not, taking the returns as a whole, by a substantial margin. Two points should be noted. In June 1967, most companies visited on interview were still fairly busy but were expecting work to fall off steeply in the autumn. Secondly, companies said they tried to keep on their work-forces in slack times because of the great difficulty of rebuilding them again if business improved. Several companies also commented on the importance of allowing the customary overtime to continue as long as possible to dissuade some men from leaving of their own accord. The figures for 1967, therefore, conceal a certain amount of underemployment.

The trend of pressure vessel production within the company

9. For the years 1962–6, companies were asked the lowest and highest proportions that pressure vessels had accounted for in total company output and in total output of the heavy fabrication shop. They were also asked if vessels were taking a larger or smaller share of shop output. Figs. B(1) and B(2) present the results.

10. Fig. B(1) shows a wide spread in the importance of vessels in total company output and it is interesting to see that for the largest producers it falls in the range between 20/30% to 60/70%. Wide fluctuations in the importance of vessels appear in this graph and, even more, in Fig. B(2), relating to shop output. Almost all these companies indicated that pressure vessels are of growing importance in the output of the heavy fabrication shop.

Technical resources

11. Table B(3) gives ratios for 1966 for the numbers of technical staff employed on pressure vessels to certain categories of production workers. The types of technical staff included are production staff, designers and draughtsmen, and laboratory staff (estimators and shop inspection staff are excluded). The point was frequently made in interviews that medium-sized companies had to support an overhead structure relatively too big for them, in that once a company had grown too large for personal direction by an owner or manager it had to take on technical staff who could frequently handle a heavier work load than the company could give them. In spite of some fluctuations, the evidence supports this: broadly it suggests that the smaller companies included in the analysis had a ratio of technical staff to all weekly-paid workers of about 1:4; this fell to about 1:8 for the largest companies in the industry. However, the position in respect of skilled production workers is remarkably similar for the medium and large size companies.

TABLE B(2)

Indicators of company activity in 1966 and 1967

(a) Index based on number of welders and platers employed in June 1967 (number employed in June 1966)=100

Index	Shopbuilt pressure vessel output group in 1966		TOTALS	
	£200,000—£500,000	£500,000+	£200,000+	
60–69	1	—	1	17
70–79	1	2	3	
80–89	—	1	1	
90–99	7	5	12	
100	1	2	3	
101–110	4	—	4	7
111–120	2	1	3	
COMPANY TOTALS	16	11	27	

(b) Average working week of welders and platers employed in June 1966 and June 1967

Average working week (hours)	Shopbuilt pressure vessel output group in 1966				TOTALS	
	£200,000—£500,000		£500,000+		£200,000+	
	1966	1967	1966	1967	1966	1967
37–40	—	3	—	1	—	4
41–44	1	1	3	4	4	5
45–48	6	6	5	4	11	10
49–52	5	3	2	2	7	5
53–56	3	2	1	—	4	2
COMPANY TOTALS	15	15	11	11	26	26

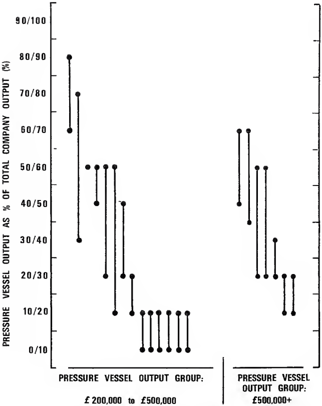


Fig. B(1). The lowest and highest proportions pressure vessels represented in total company output in the period 1962–66 (total 21 companies)

Note: one company in the smaller output group reported no fluctuations in the importance of vessel output and their return is represented by a point

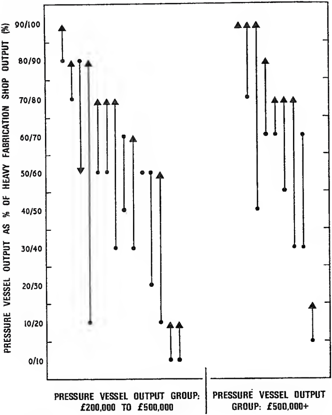


FIG. B(2). The lowest and highest proportions pressure vessels represented in the total output of the heavy fabrication shop in the period 1962–66

Notes: one company in the smaller output group reported no fluctuations on the importance of vessel output and their return is represented by a point;

the arrows indicate whether the trend of vessel output as a proportion of the total was up or down; where there is no arrow, it was constant

TABLE B(3)

Technical backing for the heavy fabrication shop, June 1966

Company category: shop-built pressure vessel output, 1966		(a) £200,000 to £500,000 (12 companies)	(b) £500,000+ (9 companies)	(a+b) £200,000+ (21 companies)
Number of workers in heavy fabrication shop	Minimum	65	113	65
	Average	177	447	293
	Maximum	495	917	917
Number of heavy fabrication shop workers to *one* technical employee*	Minimum	2·4	2·1	2·1
	Average	5·5	7·9	6·5
	Maximum	13·1	16·6	16·6
Number of all direct production workers to *one* technical employee*	Minimum	2·4	1·1	1·1
	Average	4·7	6·8	5·6
	Maximum	11·8	15·7	15·7
Number of skilled production workers to *one* technical employee*	Minimum	1·4	0·4	0·4
	Average	3·3	3·7	3·5
	Maximum	9·8	7·1	9·8

* Working wholly or mainly on pressure vessels

Product specialisation

12. Table B(4) gives summary figures for numbers of companies recording each type of product and material as a principal or secondary activity for individual companies. It is striking to see that none of the 27 companies listed reactive metals and very few gave copper or aluminium.

Design standards

13. Table B(5) gives pressure vessel design standards to which companies had built vessels. Since only the asterisked standards were printed on the questionnaires, and as no help was given to remind companies of other standards, the answers for the remaining are no doubt a severe understatement of these companies' experiences in building to foreign design standards.

Supply of dished ends

14. Twenty-two of the 27 companies had facilities for manufacturing dished ends and full details are given in Table B(6). A further 5 companies returning short questionnaires stated they manufactured ends, suggesting a total number of producers for the UK industry as a whole of about 30 to 35.

Heavy fabrication shop characteristics

15. The major shop characteristics of 26 of the leading fabricators in 1966 are given in Table B(7) including maximum crane lift, total floor area and length of largest bay.

TABLE B(4)

Product specialisation: summary table

Material	Companies* giving as a principal or secondary activity				
	Tanks	Shopbuilt pressure vessels		Site-built pressure vessels	
		less than 1″ plate	1″ plate or more	less than 1″ plate	1″ plate or more
Low carbon mild steel	16	20	19	5	4
High carbon and alloy steel	8	16	14	3	3
Stainless steel	12	18	13	4	2
Aluminium and its alloys	3	3	—	1	—
Clad steel (including stainless and nickel alloy clad)	4	13	12	4	2
Copper and its alloys	1	2	1	—	—
Reactive metals (Zr, Ti including metals so clad)	—	—	—	—	—
Nickel and its alloys**	2	6	3	—	—

* Returns from 26 companies are included in this summary table

** This heading was *not* included in the pilot questionnaire (of which 11 were returned out of the 26 included in this analysis)

TABLE B(5)

Pressure Vessel design standards used by U.K. fabricators

(Data relates to 27 companies with shop-built pressure vessel output in 1966 greater than £200,000)

(a) List of countries whose design standards have been used

Country	*Number of companies*
UK	27*
USA	27*
Federal Republic of Germany	19*
Netherlands	7
Italy	7
Belgium	2
Finland	2
France	2
India	2
ISO	2
Russia	2
South Africa	2
Sweden	2
Australia	1
Austria	1
New Zealand	1
Switzerland	1

(b) List of design standards that have been used

Country	*Design standard*	*Number of companies*
UK	BS 1500 II and III	27*
	BS 1515	27*
	BS 1500 I	26*
	Lloyds	11
	AOTC	10
	BS 1113	6
	BS 2790	5
	BS 3274	4
	BS 487	4
	UKAEA	4
	BS 3915	2
	ICI	2
	BS 853	1
	Rolls Royce and Associates	1
USA	ASME	27*
	TEMA	3
	API 650	1
	American Bureau	1
Federal Republic of Germany	TUV	15*
	AD—Merkblätter	3
	DIN	3

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* These design standards were listed in the questionnaires, all other standards were entered by repondents under the 'other standards' heading provided. All 'other standards' not asterisked probably constitute a severe understatement of their usage

16. Data relating to rolling and bending equipment is given in Table B(8), including hot and cold rolling/bending of mild steel. Machining by boring and by turning is noted in Table B(9), whilst usage of inspection equipment is indicated in Table B(10). Temperatures and leading dimensions for stress-relieving furnaces (SRF) and annealing furnaces (AF) are given in Table B(11). Altogether returns from 26 leading pressure vessel fabricators have been taken into account in compiling these tables. However, some companies did not answer all questions; in other cases, some companies did not have the relevant equipment and the question(s) therefore were not applicable to them.

17. It is important to note that, in respect of Tables B(7) to B(11), each table and sub-table stands individually and is completely independent of the data laid out in the remainder. False impressions may be obtained by attempting to cross-correlate any one table or sub-table with another.

TABLE B(6)

Facilities for manufacturing dished ends

Company category: shop-built pressure vessel output group, 1966	Spin pressing maximum			Die pressing maximum			Segment building
	Diameter	Thickness	Weight	Diameter	Thickness	Weight	
	(Feet)	(Inches)	(Tons)	(Feet)	(Inches)	(Tons)	
2	—	—	—	4·0	0·25	**	Yes
1	—	—	—	4·0	1·25	5·0	Yes
5	10·0	0·5	1·0	5·5	0·325	0·5	Yes
3	—	—	—	6·0	4·0	**	Yes
3	—	—	—	6·5	0·825	**	Yes
5	16·0	0·5	3·0	7·0	3·0	4·0	Yes
4	16·0	1·125	5·0	7·5	4·0	15·0	Yes
4	16·0	4·25	10·0	8·0	2·0	3·0	Yes
2	—	—	—	8·5	0·625	0·5	Yes
3	—	—	—	8·5	1·5	5·0	Yes
3	—	—	—	8·5	2·25	10·0	Yes
3	—	—	—	8·75	6·5	14·0	Yes
3	—	—	—	9·0	0·325	**	Yes
5	15·0	4·25	11·0	9·0	2·5	4·0	**
5	—	—	—	10·0	5·5	5·0	Yes
3	—	—	—	10·0	6·0	8·0	Yes
4	14·0*	2·0*	**	10·5	2·625	**	Yes
3	—	—	—	11·0	2·0	2·5	Yes
3	**	**	**	12·0	1·75	4·0	Yes
5	13·3	1·0	2·8	13·3	1·0	2·8	Yes
2	12·0	0·625	0·5	—	—	—	Yes
3	14·0	0·5	1·5	—	—	—	Yes

* Creep flanging

** Blank return to this question

Note: The table lists the facilities of the 22 companies returning pilot and revised long questionnaires who are dished end producers. A further 5 companies returned short questionnaires stating that they produce dished ends. These 27 companies are divided by pressure vessel output group as follows:

Group 1	£1–50,000	3 companies
2	£50,001–200,000	5 companies
3	£200,001–500,000	11 companies
4	£500,001–1,000,000	3 companies
5	£1,000,000+	5 companies

TABLE B(7)

Heavy fabrication shop characteristics of 26 UK fabricators with shop-built pressure vessel outputs in 1966 of £200,000+

(a) *Maximum crane lift (tons)*	*Number of companies*
1–50	8
51–100	7
101–150	4
151–200	4
201–300	1
300+	2
	26

(b) *Total floor area* (1,000 *sq ft*)	*Number of companies*
1–40	3
41–80	7
81–120	5
121–160	2
161–200	5
201–240	0
241–280	1
281–320	1
320+	1
	25

(c) *Length of largest bay (ft)*	*Number of companies*
1–100	0
101–200	2
201–300	4
301–400	6
401–500	7
501–600	3
601–700	4
	26

Note: see paragraph 17 of Annex B

TABLE B(8)

Rolling and bending equipment of UK fabricators

(a) *Maximum width that can be rolled or bent (ft)*	*Number of companies*
1–5	0
6–10	9
11–15	13
16–20	1
21–25	2
	25

(b) *Minimum diameter that can be rolled or bent (inches)*	*Number of companies* Mild steel (hot)	Mild steel (cold)
1–10	3	6
11–20	2	7
21–30	2	8
31–40	2	0
41–50	1	0
50+	0	1
	10	22

(c) *Maximum thickness steel at any diameter (inches)*	*Number of companies* Mild steel (hot)	Mild steel (cold)
Up to 2	2	10
2–4	1	10
4–6	3	2
6–8	2	0
8+	1	1
	9	23

Note: see paragraph 17 of Annex B

TABLE B(9)

Machining and welding equipment of UK fabricators

(a) *Maximum diameter that can be machined (ft)*	*Number of companies* By boring	*Number of companies* By turning
Up to 5	3	4
5–10	7	5
10–15	4	10
15–20	7	2
20–25	1	1
25–30	1	1
30–35	0	1
	23	24

(b) *Maximum diameter that can be automatically circumferentially welded (ft)*	*Number of companies*
Up to 5	1
5–10	0
10–15	8
15–20	11
20–25	3
	23

TABLE B(10)

Inspection equipment of UK fabricators

(a) *Inspection equipment of* 26 *companies*	*Number of companies*
Ultrasonic	20
X-ray	26
Gamma-ray	19
Hydraulic	26

(b) *Use of X-ray inspection: total length radiographed in* 1966 (1,000 *ft*)	*Number of companies*
Up to 10	4
10–20	5
20–30	2
30–40	1
40–50	2
50–60	0
60–70	1
70–80	0
80–90	0
90–100	1
	16

Note: see paragraph 17 of Annex B

TABLE B(11)

Stress relieving and/or normalising furnaces (SRF); and annealing or plate heating furnaces (AF)

(a) *Maximum temperatures* (°C)	*Number of companies*	
	SRF	AF
600–700	3	0
701–800	5	0
801–900	2	0
901–1000	3	2
1001–1100	4	4
1101–1200	2	7
1201–1300	0	2
	19	15

(b) *Length of furnaces* (*ft*)	SRF	AF
Up to 10	1	1
10–20	1	9
20–30	6	5
30–40	1	0
40–50	5	1
50–60	4	0
60+	1	0
	19	16

(c) *Maximum diameter of vessel* (*SRF*) *or width of furnace* (*AF*) (*ft*)	SRF	AF
Up to 5	1	0
5–10	3	3
10–15	8	12
15–20	7	1
20–25	1	0
	20	16

Note: see paragraph 17 of Annex B

ANNEX C

UK supply: commercial and technical factors

Personnel

General

1. In the course of the fabricators' interviews, the survey team was able to meet a cross-section of the staffs of companies including: the Managing or Engineering Director, Works Manager, Planning Engineer, Accountant, Personnel Manager, Chief Draughtsman. Interviews were rarely at Foreman level, through lack of time. This cross-section of management did provide a valuable insight into the overall operation of a company and certain similarities in terms of attitude and policy, both for production and sale, were encountered. *The views recorded in the following Annex are those of the individuals comprising the interviewing team.*

2. It was possible to form an impression of the calibre of management, although it would be clearly an impertinence to pass judgement on the quality of management staff in an industry on the basis of a brief discussion. However, certain facets do stand out: there appears to be a certain conservatism of attitude which is sometimes characterised by a lack of initiative in the search for new policies. There were exceptions, but in general the impression was formed that the revolution in attitude required for an aggressive attack on export markets would be achieved by an influx of fresh and well qualified men. These would only be attracted through being given both responsibility to shape policy and reasonable salaries, and here the size of individual companies has a major role to play. There are, of course, some very notable exceptions to the impressions gained.

3. Where conservatism of directors occurs this has an influence throughout the rest of the personnel of a company, in that attitudes permeate downwards. There is clearly a 'precedent required before action is taken' system, rooted in certain quarters of heavy engineering industry with its interlinking aspects of personnel, management, technical staff, skilled labour, training, etc. All these aspects have to be considered together as each component of the system affects the others and plays its part in making sure that as little change as possible takes place.

4. These problems are not peculiar to the pressure vessel industry, and are found in several of the older engineering sectors in the United Kingdom. A lot is said about the need to change management and labour relations, but in the survey's opinion this will only come if the necessary injection of 'youth' and changed 'image' comes into the managements of some of the companies in the pressure vessel industry. Again, in contrast with continental practice and some leading UK companies, tbe general lack of human contact between shop management and labour was striking; this is part of the proverbial 'we' and 'they' attitudes which are at the root of most productivity problems.

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Management

5. If the main role of management is to provide the most efficient day-to-day operation of a company, combined with the possession of the tools and the ability to use them (which is necessary for the planning of a profitable future), then there is room for improvement in the management of certain quarters within the pressure vessel industry. A number of examples were encountered of the lack of knowledge by management of advanced costing techniques as an essential screen for the planning and production of the most profitable items. Thus management tended not to keep statistics of output by product category; management might invest in new plant without estimating the likely return on expenditure; management frequently did not attempt to allocate overheads accurately, so that the varying profitability of alternative lines was concealed. Some companies adopted particular costing methods without noticing their implications for the company's market position—a blanket overhead, for example, would attract exotic work since many other companies applied higher overhead charges to these difficult vessels. These were only general impressions, and it must be emphasised that some of the companies interviewed had very sophisticated systems of costing.

6. From the standpoint of the future, there were significant gaps in the knowledge of market trends for major process industries served by the pressure vessel industry. A number of fabricators stated that they did not think it necessary to find out the uses to which their vessels were being put. Without this knowledge, however, the most simple form of market research was impossible. A method of closing these gaps is discussed later in this Annex.

7. On the organisation and control of their workshops, many companies agreed they had been remiss in the past. The shops seen were often fairly old, cramped in space and inconvenient, although there were commendable exceptions. There were, however, many indications that the management of the industry was aware of its shortcomings, and that steps in some cases were being taken to remedy these. The major concentration, however, was on the reorganisation and rationalisation of fabrication shops, which, however important, would only show appreciable results if the other problems of labour productivity and markets were also tackled.

8. There was considerable frustration in the industry which obviously contributed to 'ossification' of attitudes. This frustration was engendered by a number of factors:

that after bitter complaints in 1966 from their customers about lack of productive capacity, the demand should fall right away in 1967;

that enquiries kept coming in but few of these related to work for which orders could actually be placed;

that despite cutting profits to zero on many orders, foreign competition was coming in at prices which were sometimes 10–15% below those of British prices (during 1966–67).

Staff

9. The main types of professional staff employed by fabricators are: works managers, planning engineers, design engineers, sales managers, metallurgists and accountants. It was not possible to meet the full complement of staff in all companies visited, but in most cases two or more staff representatives were included in the discussions. As in all industries there was a fair range of ability; whilst the general impression was of a

good level of competence, the weakest areas were perhaps those of sales and costing. The industry's faults appeared to arise not so much at the level of its professional staff, but at top management or board level where the major policy and financial decisions were made.

10. No complaints were heard about the difficulty of getting professional staff. The training schemes for staff, including short courses, were quite well developed in most companies, and genuine 'staff career planning' systems were encountered occasionally. The development of a strong group of technical staff does fall to a considerable extent upon the personnel department. However, technicians and laboratory apprentices do present a problem. These youths used to represent an intermediate stage between craft training and higher education: five 'O' levels would be a typical qualification. Recently firms have found they are going on to technical colleges or some other form of further education instead of filling these posts. A revised career structure may therefore be needed.

11. More attention should, it is felt, be given to the drawing office, for if it is conceded that technical innovation is one key to the problems of the pressure vessel industry, the part played by the drawing office and, in particular, the design team will be the most important. The character and quality of a drawing office is usually well represented in the person of the Chief Draughtsman. This post should not be regarded lightly, and we suggest that many fabricators should ask themselves if the enthusiasm in their drawing office is all that it should be.

12. Drawing, as distinct from design, is not necessarily an interesting task. A draughtsman on whom depends, or will depend, the design of vessels and, therefore, a great deal of engineering innovation, must be given the necessary enthusiasm. Of course, this comes from the interest in his work shown by his superiors, especially the Chief Draughtsman, and the extent to which his ideas are encouraged.

Skilled labour

13. Most informants found skilled labour hard to get, but the worst areas appeared to be the South, followed by the East and West Midlands. People's dislike of moving and lack of housing were given as the main explanations of failure to attract men from the areas with high unemployment.

14. Several informants pointed out that heavy fabrication work was arduous and demanding, and often done in hot and cramped conditions. Men could find easier jobs offering as much or more money. The fact that the work required skill and intelligence was more often regarded as a disadvantage than an advantage from the point of view of recruiting and holding labour. Unless some means can be found of raising wages, or possibly of downgrading some of the skilled jobs, the position could get worse. Already some companies relied on an ageing work-force.

15. Within this common picture there were regional variations in 1967, outlined below:

Northern England and Scotland	The labour situation was generally less tight than in the Midlands, and labour turnover rates relatively low. The quality of the workmen was said to be good, but restrictive practices were very evident;

Midlands and parts of Yorkshire	Informants here were almost unanimous in praising the skill and energy of their craftsmen, but the labour situation was one of the tightest in the country, and it was very easy for men to move. This led to severe inflexibility in working; companies lost men unless they offered the traditional working week, consisting of day shift only with the desired number of overtime hours. These accepted norms can vary from one factory to another and were hard to change. They represented a severe operating limitation in a fluctuating market;
South East	The labour situation was as tight as in the Midlands, with the same effects, but from companies' comments the craftsmen did not seem to be of quite the same high calibre as in the Midlands, and were even harder to keep. Restrictive practices were less evident.

Trade Unions

16. The first point to be made is that the companies seen varied very widely in regard to union organisation: there were non-union shops (where unions were not recognised in management negotiations but the men, of course, might belong to one if they wished); open shops and closed shops; shops where all or most of the men belonged to just one union (Boilermakers Society, Municipal and General Union); and shops where the management dealt with up to six unions in regard to pressure vessel fabrication. The unions most commonly found were the Boilermakers Society, the AEU, the TGW, the Sheet Metal Workers and the Municipal and General Union. The variation between companies reflected partly their differing industrial backgrounds, and partly regional and company traditions. Totally different situations could be found in factories a few miles apart.

17. The most important individual union in pressure vessel construction was found to be the United Society of Boilermakers, Shipbuilders and Structural Workers. In most heavy fabrication shops all the skilled workers belonged to this Union, except the machinists and certain welders who may belong to the AEU. In the purely stainless steel shops the Boilermakers were most likely to be replaced by the National Union of Sheet Metal Workers and Coppersmiths.

Productivity

18. Labour problems seem to be notably less troublesome with respect to the Coppersmiths than with the Boilermakers, and companies with non-union shops naturally enjoyed a high degree of flexibility in the organisation of work and in methods of paying their men. Some companies with union shops enjoyed a similar degree of freedom: in the final analysis, differences between companies in this respect must be ascribed partly to personalities on both sides in the company and local union staff, and not necessarily to the policy of a particular trade union or to a regional tradition.

19. It is, however, local union policy to resist flexibility between trades and rigid demarcation was observed in some union shops, this appeared to be particularly where the Boilermakers Society was strong. It should be noted that there is a definite difference

in the attitude between shop stewards and local union officials on the one hand, and the national trade union leadership on the other, but it is the former which seems to be the most relevant in determining the degree of labour flexibility existing in a given shop. One company had persuaded the unions to agree to a pool of three skilled men who worked in a variety of trades as required while the rest kept to their own crafts. Other companies, both in the north and in the south, had achieved a higher degree of flexibility than this with men in different craft unions working easily together, and men occasionally working outside their own crafts. Some companies where rigid demarcation was observed claimed that they would not want anything else. Other companies' struggles, however, to achieve flexibility suggest that there is a significant saving to be made, and the subject is discussed in more detail under 'demarcation'.

20. Other comments heard were that the unions resisted the introduction of new machinery, of work study and of incentive methods of payment. One company in Scotland said that the unions had completely blocked the introduction of advanced machines by their claims for overmanning and overpayment: in the other companies visited automatic welding equipment and other forms of machinery had been introduced without difficulty. It does seem to be true, however, that unions tended to resist the introduction of work study and incentive methods of payment. Most of the successful schemes operating in companies visited had been introduced in the teeth of union opposition. Some companies were still unable to put such schemes into effect. Nevertheless, the impression was gained that companies sufficiently determined and patient could achieve most of what was desired, with the exception of flexibility between trades.

21. The control and measurement of productivity depends on work measurement and the setting of standards. Most of the successful companies seen had some form of measured work in operation, though it might be a crude system in all companies because of the high costs of carrying out a full operational analysis in this industry. There is scope here for the development of a standard but flexible system of work measurement, job control and costing for the smaller fabricator.

22. Several companies which had put in work measurement and incentive payment schemes recently claimed an immediate increase in productivity, accompanied by a drop in overtime. These improvements can be attributed partly to the linking of wages to output, but also to the better organisation of work that was usually a side effect of job analysis. Incentive payments alone were found to be of limited value in some regions: the men have target earnings figures as they have a target length of working week and work only hard enough to achieve this sum; the increasing weight of taxation on additional earnings was also said to be an important deterrent. The achievement of a high and consistent rate of output, therefore, is a complex problem of human relations in which the management of the shop is more important than the method of payment used.

Payment schemes

23. Examples were found of all the main payment systems amongst the companies visited; simple piece rate, basic rate plus individual bonus, basic rate plus shop bonus, and simple basic rate. Many companies had just changed or were about to change the system, usually towards individual bonus schemes. Bonus schemes may be on a shop basis or an individual basis and the latter, of which Measured Day Work was an example, offered the advantages of personal incentive and the possibility of more

accurate cost analysis. However, when the bonus scheme was aimed at individual jobs, i.e. piece work, and a man's wages were entirely or largely made up of piece work payments, the importance of the rate fixed could lead to argument and to inaccurate standards and often out-of-date rates. It was also said that the close control a man had over his own wage packet may for personal reasons, or more likely from Union pressure, make him change his pace at the end of the week to bring his wage packet to the 'norm'.

24. Measured Day Work is designed to overcome these problems and is a long term, low value bonus system. The bonus is no longer aimed at jobs but at the work done per day over a period of, typically, 3 months. Standards have to be set up and these are based on historical records. A man's wage for three months depends on his performance in the previous three months and is adjusted at the end of each three months. The bonus involved may be in the order of 10% with perhaps another 10% based on length of service, quality, and time-keeping.

25. The advantage of an individual bonus scheme is that the incentive, being very personal, is the maximum. The disadvantages are:

the complication and, therefore, the cost of setting up and operating it;

constant argument about the 'rate for the job';

an unwillingness of any one worker to help another;

the almost moral objection that skilled men would be paid according to their speed rather than their quality.

26. Measured Day Work maintains the advantage of an individual bonus scheme, but keeps the supplementary component of the wage quite small and subject to variation over a long term, eg three months. As the base on which the system is built is measured and not argued, the system offers an advantage that individual bonus schemes should but usually fail to offer, viz. complete and accurate costs of production by vessel and operation.

27. An alternative system of payment which has its own particular advantages is a shop or factory bonus system—one could call it profit sharing—with an individual merit payment recognising skill, versatility and rapidity, and administered thoroughly impartially. Such a system of payment would encourage the concept of a team while recognising individuals in their own right. At the risk of over-complication, it may be worth investigating the possibility of combining Measured Day Work with shop bonus.

Demarcation

28. The most important weapon of the unco-operative shop steward and the biggest difference between British and European labour lay in demarcation.

29. The fact that it has been practised within the whole of living memory is the main reason why its significance is not always appreciated by management. Perhaps it is a problem too big to attract specific consideration. Naturally, management has learned to live with it, but it could lead to more useful results if management put its principal effort into reducing demarcation rather than regularly changing the payment system.

30. The specialisation of trades, the necessity for continuous practice to maintain skills, and the need for separate production operations means that at any one time nearly all skilled workers will be doing one type of job only, and that the majority will, in fact, be doing only one type of job all the time.

31. Pressure vessels are all dissimilar. Since the work load fluctuates, the concentration of work in the heavy shop varies from plate forming to final assembly and so on. Thus the amount of work available at any one time for each trade must vary, and because of the 'rules' of demarcation, it was quite possible for one group of men to be idle while the others cannot cope with the work load and thereby cause a bottleneck in production. This has a general effect on the whole of the shop, and productivity may be reduced through a number of individual causes.

32. To illustrate the above, skilled workmen of each of the two leading trades may not carry out work 'belonging' to the other, or belonging to a semi-skilled trade even though production bottlenecks may result due to a semi-skilled labour shortage. A classic example of the former is tack welding, and of the latter weld chipping-out. Under present conditions, it is rather unlikely that platers would pick up a welding torch even for tack welding, a task easily within a plater's capabilities. So, after the plater has bent or rolled the plate and pulled it into position, a welder must be called to carry out a short operation; either the welder interrupts his other work, or the platers have to wait for him, entailing a loss in productivity in either case. Again, if the welder refuses to chip-out, how much time, especially while hand welding, is lost waiting for the chipper-out? If the operation of a welder and his mate are really subjected to work-study it would be revealing to discover the proportion of the time of each which is spent waiting for the other.

33. Demarcation can actually occur within the same trade and, it is understood, a classic example of this is that AEU welders are not allowed to work alongside Boilermaker welders.

34. The above are examples of widespread practices and their adverse effect on the essential flexibility needed for shop planning cannot be unduly stressed. No quantitative figures from the information gathered in this survey could usefully be suggested for the increase in productivity that would accompany an interchange of work between trade, but it is certainly considerable.

35. A general free-for-all in work distribution is not suggested, but the following steps would overcome most of the problems and align the UK with most other European countries:

the formation of a pool of exceptionally skilled workers, who could be transferred from plating operations to welding as the production required;

the possibility of all platers and welders doing the simplest tasks of the others' trade as the need arose;

the possibility that any skilled man may carry out tasks, themselves unskilled, but forming part of his overall skilled operation.

The two basic trades of welding and plating are here defined as skilled, and this represents a sensible breakdown of trades in the Boilermakers Society. Among semi-skilled workers an almost complete flexibility should be maintained, again with the possibility of men able to do two jobs. If this were brought about, an associated modification of wages would be necessary, and it seems perfectly fair that the men able to do two jobs should be paid more than those with only one expertise.

36. *It is one of the major findings of the survey that if the practices associated with 'demarcation' were to be substantially reduced it would enable the UK pressure vessel industry to maintain and to improve its position competitively on a world basis.*

Training

37. The quality of skilled men in this industry, as in most of the British industries, is as high as anywhere else. The foundation for this skill is in the five year apprenticeship system which, for all its slowness, produces craftsmen of high standing. At the same time the apprentice has many other, less desirable, traditions instilled into him.

38. Apprentice training was now more refined, distinct plans and schedules were now followed, and real progress was being made under the auspices of the Industrial Training Board. Government rebates rendered the purchasing of training facilities an interesting proposition for companies, and many training schools visited were often in the process of expansion. Training officers were invariably enthusiastic and often extended the training into extra-curricular activities.

39. Craft apprenticeships usually began with between nine months to one year in training school, followed by a year of short periods in different departments. By then the apprentice was in a position to choose his craft, and spent the next three years on a more specialised training to become a plater, machinist, welder, etc. according to his choice.

40. Both technicians (including draughtsmen) and student apprentices received a shortened version of the craft apprentice basic training.

41. Few criticisms of apprentice training could be found. The only change of significance suggested is that a normal goal for top apprentices should be to become dual trade craftsmen.

42. It is also worthwhile mentioning that the supervision of apprentices, once they were in the shops, was often unsatisfactory. The idea of a 'senior craftsman' looking after one or two apprentices all the time should be considered seriously, as an older man had more patience to teach and more experience to pass on, but was not likely to be as fast a worker as a younger man.

43. The apprenticeship system was the only system whereby a man could be considered skilled. If he was not, therefore, skilled by the age of twenty-one, all the doors were closed. This situation appears irrational in view of:

the shortage of skilled men;

the Government policy of redeployment, which by its very nature involved the retraining of men from a dying industry to an expanding one.

44. It is not suggested that the apprentice system be relegated, but simply that if a man of 30 or 40 years of age is able to follow a satisfactory training and match the necessary standards, this ability be recognised by management and unions. This is particularly true for welders whose work is often in a narrower field than platers and who could, therefore, be trained more quickly. Welders, though a full 'skill' in the Boilermakers', are not recognised as such in the AEU unless they are fitter-welder, for

example. It could be suggested further that the welder who is completely versatile (being familiar with hand and machine welding, different techniques and materials) should be the product of an apprenticeship, while the more specialised welders who might concentrate on one type of machine should be trainees from Government centres and other courses.

45. Training, like demarcation, can be used as a means of protecting those who have already been trained against possible dilution. This and corresponding aggravation of the labour shortage should be minimised so as to further improve Britain's competitiveness in pressure vessels.

Sales and marketing

The market conditions for pressure vessels

46. In respect of the relationship between fabricators, contractors and final users it can be said that the majority of pressure vessels pass through the hands of contractors and are for installation in complete new plants. Sales of vessels directly to final users are more likely to be for replacement or modification, or for installation in new plant where contractors are not very active, e.g. food plant and pharmaceutical plant. The predominance of stainless steel in these last mentioned industries explains why stainless steel specialist fabricators have a larger proportion of sales direct to final users.

47. There are other cases, such as: when a fabricator is in the same group as a contractor; when a fabricator offers complete plant; and in rare cases when a fabricator is owned by a final user. These are rather exceptional cases and only the two most important sales methods are considered, viz. direct to user and via a contractor. Some comparisons between the two methods are given below.

48. Contractors are a most important part of the pressure vessel market. They do not actually generate pressure vessel demand, but they do determine where the pressure vessels are built. Firstly, on a world-wide basis the British-based internationally operating contractors, in competition with contractors operating from other countries, bring a potential pressure vessel order into the UK. Then, secondly, both for these overseas orders and for home orders, the contractor chooses his would-be tenderers and makes the final choice of pressure vessel supplier.

49. The methods of choosing the pressure vessel supplier are not particularly subtle. Requests for quotes are put out to several fabricators, specifying the vessel often to the stage of a complete drawing. A delivery date and a dead-line for the quotation are specified. Provided these timing exigencies were accepted by the fabricator, the one putting in the most reasonable price received the order.

50. When both demand and supply gave rise to a reasonably balanced growth such a system worked well enough. But as soon as an appreciable imbalance occurred the market became either a buyers' market or a sellers' market. For about the last decade the British pressure vessel industry had often been in a position of disbalance one way or the other to the detriment of the industry and of the customers.

51. For example, in 1966 there was a sellers' market, and the symptoms were as follows:

British fabricators offered long delivery times;

they often exceeded the promised delivery time;

the British fabricating industry (according to the customers) had an indifferent attitude towards customers;

British prices lost their keenness.

52. These effects generated considerable dissatisfaction among the purchasers of pressure vessels, and quite a considerable number of pressure vessel orders were placed abroad. Of course, under these conditions the British fabricating industry made little attempt at direct exports.

53. During the last months of 1966 and the first three months of 1967 the pendulum swung completely the other way. During the remainder of 1967 pressure vessel orders were at a low level and fabricators met difficult business conditions to such an extent that a large part of the industry made little profit, or even losses. The price-cutting competition occurred amongst and between regular fabricators who commonly accepted work at a loss to be able to keep on their labour force. The situation was further aggravated through an ignorance by some fabricators of costing techniques, which could result in making a quotation with, unknowingly, no profit content.

54. The influence of non-regular fabricators may be considered minimal as the types of vessels they can make are not sophisticated and affect only a small low value part of the market. Contractors, whose vessel requirements are normally quite sophisticated, do not appear to use anything but regular fabricators as *prime* sub-contractors.

55. It is ironic that, in addition to the competition between UK fabricators, competition from foreign fabrication industries is still very much present during depressed periods of UK demand, as there is usually at least one continental country in a similar state of depressed home demand at any given time. During 1967 this was West Germany, and in 1965 and early 1966 it was Italy. These countries, in contrast with the UK, did turn to export markets when their home markets were depressed.

56. The foreign competition (which during 1967 represented price differentials of between 15 and 30% on many large and/or sophisticated vessels) had taken a certain proportion of the UK pressure vessel work available and caused bitterness amongst some UK fabricators. According to calculations, the foreign prices were often little above material and labour-costs, an allegation which has been supported to a certain extent by some of the European interviews.

57. The fluctuating demand for pressure vessels is not a phenomenon limited to this one industry; the fluctuations are phased with (but not directly in-phase with) the whole country's economic peaks and troughs, and the 1967 trough in pressure vessel demand followed the July 1966 Government measures. Nearly all other mechanical sectors were affected. Whilst there are grounds for hope that such 'stop/go' policies may be alleviated by the devaluation in November 1967, a more sensible approach for a fabricator would be to accomodate his company to these fluctuations and to see how their effects can be minimised.

58. The first measure should be to endeavour to widen the potential market through exports. These are dependent on the country's monetary and foreign trade policies.

The 1967 devaluation is favourable to an increase in the international competitiveness of the UK industry, provided no prohibitive measures were to be taken by countries representing potential markets for exported pressure vessels. For instance, there was a 10% tariff barrier in the Common Market operating against the UK, but with a devaluation of 14·3%, implying a price reduction of some 4–6%, this should now be minimised. The consideration of entry into the Common Market could completely change the present home-market bound approach, particularly with the concomitant greater pressure of imports into the UK from the Common Market.

59. A large single economic market made up from a number of individual national markets has the clear advantage that peaks and troughs in demand do not usually occur in every part of it all at once, so that total market demand tends, therefore, to be less fluctuating.

60. Many British fabricators, in order to continue profitable business, should change their negative approach to exporting and endeavour to evaluate potential export markets. Overseas agents and offices should be set-up in areas of interest, for example in the European and American market. Some of this marketing effort, and certainly the market research, could be shared for exports, and it is felt that a trade association could help to organise a viable system.

Purchasing methods and engineering

61. Nearly all the fabricators expressed the view that either it would not be worth their while to increase their attempts at technical innovation, or that their present attempts brought them little satisfaction. They tended to blame this on their customers' purchasing methods, and considered contractors to be more blameworthy than final-user customers.

62. Technical innovation requires development and design facilities of considerable cost, adding to overheads, but this enables the fabricator to offer the most sound pressure vessel in the best technical and economic terms. New techniques often involve new equipment, but the technical standing of a fabricator rather follows on from his design and development facilities.

63. It is important to distinguish quality from technical innovation as, although they are often associated, they are not necessarily interdependent in a straightforward manner. Contractors' appreciation of quality is discussed later.

64. The contractors' appreciation of a company that could offer technical innovation appeared to be negligible. Cases of collaboration between a fabricator and contractor at the design stage appeared to be rare. The contractor appeared to expect nothing but a manufacturing service from the fabricator. In many cases the vessel specifications were already virtually complete. Not only were the design standard and material specified, but the complete drawing was often included. All that remained frequently for the fabricators' senior designers was to check the work of the contractors' design staff. It is considered that collaboration at the design stage, with the mechanical design of the vessel in the hands of the fabricator, is essential.

65. With the prevalence of local buying in home and foreign markets resulting mainly from high transport costs, there can be little doubt that Britain's future exports must be

based on a high engineering reputation, with the emphasis on advanced design and the use of sophisticated materials and techniques. The British pressure vessel industry should also concern itself with productivity. Continuing improvements in productivity are absolutely necessary to enable the country to continue to compete with the Italian and German industries.

66. If the contractors are to encourage technical innovation in fabricators they must start by revising their purchasing techniques, in particular by developing the use of time and money saving procedures such as negotiated ordering and very limited tender. They must be made to realise that their own competitiveness would be improved further with a strong and technologically oriented hardware industry behind them, particularly in export markets. The present cost of tendering is enormous with respect to overall costs as success rates of fabricators are so low: about 5%–10% was not uncommon in 1967. This figure includes quotes on budget enquiries which, at present, are not necessarily marked as such by potential customers. To ask the fabricator to take on more responsibility for design would not be acceptable unless his success rate were increased considerably. Negotiated ordering would be particularly helpful for very big specialists by enabling them to plan both their fabrication programme on a medium term basis and their development effort.

67. It seems certain that fabricators have a good case when they say contractors give them little credit for their attempts at technical innovation.

68. Fabricators also often attack contractors on the grounds that quality is not recognised, which gives rise to all the bitter complaints about contractors giving orders to time-to-time and low quality fabricators. No evidence was found to support these allegations. Contractors' buyers are not necessarily engineers, but they are hard-headed professionals. They have, nevertheless, a basic list of acceptable fabricators, which list is controlled by technical staff.

69. The fault is rather that after the receipt of the large number of tenders the engineers no longer have effective control of the tender appreciation. Thus there is no individual tailoring of a given vessel to the ideal fabricator. A technical appreciation is not generally included in the final tender analysis. The occasional opportunity occurred of speaking to members of engineering staffs of contractors. They explained they had little influence over the buyer during tender analysis, but that once the order was placed for a pressure vessel it was up to the project engineer to ensure delivery of the goods.

70. There appeared, therefore, to be a real problem of communication both between fabricators and contractors, and between the commercial and technical staff of each.

71. The following changes in contractors' present buying methods are therefore suggested:

that sophisticated vessels often be purchased by negotiated ordering;

that the mechanical design of vessels be left to the fabricator;

that, for orders placed by competitive tender, the requests for quotes be given to a limited number of fabricators for each vessel;

that most of those requests for quotes which are for costing purposes only be eliminated, and such data be calculated by the contractor's own estimating department. The remaining 'costing only' requests should at least be clearly marked as such;

that contractors' purchasing departments should work in co-operation with the engineering staff, in particular for tender appreciation when judgements of a fabricator's particular design and production facilities are necessary.

Fabricators' selling methods

72. Pressure vessel purchases were found to be almost invariably initiated by the purchaser, in the sense that the selling methods of many fabricators did not go any further than reminding potential customers of their existence. A further step could be taken by the fabricators, that of reminding the customers of their existence in the context of specific jobs.

73. Two basic approaches were used by fabricators: travelling representatives who contacted contractors at buyer levels and management contact which took place at higher levels, often at social functions. The relative importance of the methods varied and, in general, the latter method was considered more important by the larger fabricators. Personal contacts really are quite important when it is considered that the majority of UK pressure vessel demand is covered by about twenty contractors and ten final users. The number of large customers is thus small enough to enable the establishment of adequately close contacts. The sometimes secondary importance of salesmen, with respect to contracts won through management contacts, partially explains why most fabricators only have salesmen of technician training or less. For most fabricators, direct exports fitted nowhere into these arrangements.

74. Once again, any change in the system could only take place if market conditions were changed. Ideally the selling, purchasing and designing of pressure vessels should often involve collaboration between supplier and purchaser—and particularly collaboration at a technical level between engineers of both sides. Clearly in such circumstances the status and importance of salesmen would be appreciably increased.

75. Fabricators with a slightly more advanced sales technique backed their sales effort with desk work. This involved their being informed on new projects which could lead to a pressure vessel order through the analysis of various trade publications. This was the only existing example of industrial 'intelligence' and it is considered that very much more effort should be put into market research.

76. Much of the market research deemed desirable is fairly massive and sophisticated and could best be done by a combined effort, for example through the auspices of TIPA. The following information should be made available to the subscribers:

market breakdown of materials, pressures, sizes and 'class' by function and by user sector. Trends would also be discussed;

market conditions existing in the UK and overseas and the identification of those types of vessels most likely to be sold successfully;

'intelligence' on the future plans of leading chemical companies, etc.

77. It is considered that an export market survey requires top priority and that by following it British fabricators would be in a stronger position to take realistic decisions about export plans.

78. It seems that essential steps in exporting are the setting up of overseas sales offices, representatives and agents, and the carrying out of positive selling, ie the sales managers should actually visit American and European contractors and final users, etc. and expound their abilities. Market research is not the only aspect on which combined efforts could bring results.

79. Instead of every fabricator having to inform individually every customer of his existence, a 'British Pressure Vessel Manual' might be published. In it every member of the Trade Association would state his product range and specialisation. Also in the 'Pressure Vessel Manual' fabricators could be Class I or Class II and, if both, separate workshops would be implied. Here Class II could be defined so that, by and large, Class II vessels could not economically be made in a Class I shop.

80. The various points made in this section are as follows:

fabricators selling methods should become more technically orientated;

market research systems should be set up centrally for both home and export markets; British fabricators should start contacting potential overseas customers and set up overseas agents and offices;

under the auspices of the trade organisation a manual describing the British pressure vessel industry and its members should be produced.

Design

General

81. If vessel design can be regarded in two stages, chemical and mechanical, it is considered that the latter should be the task of the fabricator. Thus, from the chemical requirements, ie operating conditions, the overall dimensions and position of openings, the fabricator should take over and produce complete drawings. Only in isolated cases should a fabricator increase his share in the 'chemical' design.

82. An apparent implication of the above recommendation is that fabricators' design staffs would need to be increased to cater for the increased design work. However, it is considered possible that the present mechanical engineering design complement may be adequate; indeed, an equally good case could be made to minimise the design overbeads by using more intensively the design staff already in the industry. The limitation may occur rather in the poor communications between the design offices of the fabricators and their sales staff, and the associated need for sales staff to educate the final user on cheaper methods of design and fabrication of pressure vessels that could serve the users' needs equally well. This could include, for example, the further encouragement of users to specify vessels to BS 1515 rather than ASME Section VIII or other codes.

83. Fabricators' drawing offices varied from about three draughtsmen for a small fabricator (with perhaps 60 manual workers) to between 20 and 30 for a large fabricator (with perhaps 500 manual workers). One in three of the draughtsmen, or less, may be designers in the sense that they can take care of the original calculations and design of vessels.

Modifications

84. Chemical plants, unlike atomic power stations, are never completely designed before construction begins. About the last thing to be confirmed is the piping arrangement. Thus the position and size of nozzles in pressure vessels are often subject to changes after construction has started.

85. Contractors can see no way of cutting down these modifications although fabricators suspect many of them to be unnecessary. The cost of the vessel may not be directly increased by a modification, but the drawing office time lost and bad effect on the production planning do cost the fabricator more than he dares ask the customer to pay. The situation is further aggravated by the fact that nozzles, being a forged component, have often been a bottleneck and re-ordering can cause a serious delay. The situation in 1967 was said to be improving.

86. It seems that fabricators will have to accept modifications and the following method is suggested which should alleviate the difficulties. It depends on the fact that openings are, or can be, made late in the construction of a vessel provided the necessary materials are available.

87. After the design and tender price of a fabricator has been accepted, the principal dimensions and materials should be confirmed. Similarly the size of openings should be confirmed so that forged components could be ordered. The position of the openings should be confirmed a little before work on them is due to begin.

88. These dates should be firmly written into the contract. Any modification coming after its guarantee date would be subject to a penalty to be written into the contract of sufficient magnitude to partially or wholly recompense the fabricator for his true losses resulting from the delay.

89. Such a method would give contractors all the freedom they should need, and protect fabricators against serious changes in their production programme, but its adoption is dependent upon the existence of mutual understanding between the contractor and the fabricator. These proposals have no practical precedent on the continent and would therefore represent a unique innovation if adopted in the UK.

Estimating

Policy

90. All companies practised some screening to identify work they cannot make; either by refusing to tender or by sub-contracting. But apart from this, the degree of screening on requests for quotes was found to be generally very low. Selective bidding policies were sometimes found and these were associated with progressive companies. There was seen to be an enormous effort—particularly in 1967 when orders were so few—put into estimating and quoting on everything which remotely resembled a potential order.

91. It is suggested that every company should define and publish its principal activities and be reasonably rigid in following a policy of only accepting work within its defined categories. The fact that every company should do this simultaneously is another good reason for co-operation through the Trade Association and the publication of a 'British

Pressure Vessel Manufacturers Manual'. This, of course, should not hinder each fabricator from developing a market outlet for a specialised line of vessels and of adapting its structure to exploit the market opportunities thus created.

Method

92. The usual method of estimating is to list and cost materials, estimate the manhours (by trade) involved in the vessel construction, add to the labour costs thus calculated a block overhead of 200% or more, and add the profit (10% to 15%) to the total. Transport may or may not be added separately to the overheads. Draughtsmen are usually excluded from the direct labour costs, and the definition of direct labour does vary somewhat from company to company, with corresponding changes in the overhead rate. A fairly common alternative to counting all labour directly attributable to a given vessel is to consider only key skilled workers as direct labour.

93. With regard to the allocation of overheads, many companies have considerable difficulty in arriving at a just distribution which matches market conditions. Systems vary from a block overhead on the direct labour, to a different overhead according to the individual shop, or even the individual machine. For the overheads associated directly with a shop or machine (mainly consumables and amortisation), the allocation is fairly easy except that simple vessels cannot afford the overheads associated with equipment for heavy vessels. This is why low class vessels are virtually unmixable with sophisticated vessels from the production standpoint. Facilities for design, development, computer analysis, etc. present the real problem in the distribution of overheads. The simple vessels cannot afford the weight of these overheads and neither can the sophisticated ones since, to concentrate the overheads on them alone, could increase their cost beyond competitiveness. This problem is closely associated with the market conditions and the lack of incentive to be a technical innovator.

94. Most estimators were ex-craftsmen who relied on their experience to estimate the labour input. This system reflected the basic lack of real production figures and historical costs to help estimating, and partly explained why accurate estimates of labour costs were not obtainable. It was understood that the Union representatives were opposed to more objective methods, but such methods (eg work study) now need introduction if a real improvement in estimating accuracy is to be achieved.

95. In all companies the relationship between sales, estimating, design, planning and control departments should be examined as these departments were all interdependent, and a false separation can cause difficulties.

Procurement

Steel plate

96. Although not always the 'critical path' in raw material procurement, steel plate can be considered the most important, being, as it is, the basic material for fabricated pressure vessels.

97. Due to the complexity of steel specifications with regard to content and treatment, and the large variety of possible dimensions, planned steel stocks of anything but simple carbon steel are considered impossible for any one fabricator. The only exception to this is likely to be with a manufacturer of specialist vessels, eg cryogenic vessels, who uses only one grade of steel.

98. Considerations of complexity of choice have also prevented the setting up of specialist stockholders for pressure vessel steels, and virtually all steel plate for pressure vessels is purchased directly from the mill. Since steel prices are standard the fabricators place their orders directly with the steel supplier. It should be noted that area stockholders could serve a useful function through:

(a) the grouping of fabricators in an area so as to generate group orders;

(b) the BSC only effecting delivery against minimum order levels of, say, 50 tons as currently practised in the USA thereby forcing the fabricators to plan their purchases more collectively.

99. Delivery of plate proved, particularly in 1966, to be a cause for delay in pressure vessel production during periods of high demand. Steels cited as causing particular trouble included molybdenum-containing steels, 9% Ni steel and stainless clad steel. In 1967 with the steel industry itself working well under capacity almost complete satisfaction with deliveries was to be found amongst fabricators.

100. The survey team received quite a large number of complaints about steels, especially concerning delivery of laminated plate or plate with inclusions or plate with a poor surface. The discovery of an internal fault at an advanced stage of fabrication could be expensive, so many fabricators undertook their own ultrasonic testing of plate. Fabricators also criticised the extra charge (20%) for ultrasonic testing at the mill.

101. There was no simple answer to the question of whether steel mills should give guaranteed properties. Not all applications of the same steel required the same quality guarantees, and a quality guarantee could only be based on imperfect measuring techniques. More effort should be put into international agreement on steel standards and, if international progress was too slow, the BSI should produce an interim national standard.

102. It should be noted, with regard to ultrasonic testing, that despite arguments from steel producers about too large a reject rate, it would be less expensive to concentrate the ultrasonic testing apparatus at the steel production plant, thus avoiding duplication of capital investment and the high costs in time and transport of replacing steel plate found faulty at the fabricators' factory. Mill ultrasonic testing, without additional cost to the users, appeared to be normal continental practice according to the European interviews.

Forgings

103. Forged components are purchased by pressure vessel fabricators in much the same way as contractors purchased pressure vessels, that is by competitive tender. As with the pressure vessel industry, the forgemasters themselves were very short of orders in 1967 and suffered from success rates on quotes of the order of 5%. During periods of high demand, however, deliveries for forged components lengthen considerably, and often become the critical path in materials purchasing.

104. Many of the problems of the forging industry are similar to those of the pressure vessel industry and a study of the former would probably give very similar findings to those of the present survey regarding capacity, personnel, market conditions, design standards and equipment. The supply of forgings from the forging industry must be

at least as good as the supply of pressure vessels expected from the fabrication industry for the fabrication industry, in fact, to be able to achieve its anticipated vessel supply rate. Certain measures recommended for the fabrication industry in the present survey are therefore probably applicable to the forging industry as well.

Electrodes

105. One other concern was found amongst fabricators regarding the supply of electrodes. The multiplicity of brands was confusing and considered unnecessary. In fact some rationalisation of consumables supply would appear desirable.

Dished ends

106. Though not a true raw material, dished ends are worthy of a special mention since they can become a source of delay in pressure vessel manufacture. On average the supply of dished ends, by a limited number of pressure vessel fabricators to other members of the industry, seems to match demand; but, like pressure vessel demand itself, demand for dished ends is very variable. Fabricators dependent on their competitors for dished ends expressed some fear that during peak periods of demand the supply of these components could become critical. However, a serious reform of the present dished-end supply position would not appear necessary other than for a continual improvement in service.

Production

Equipment

107. The list of machinery in a well-equipped heavy fabrication shop includes:

- plate edge flame cutter
- plate edge planer
- circular and profile flame cutters
- rolls
- bending equipment
- pressing equipment
- welding equipment including fully automatic machines with synchronised rotators and moving beds
- machine tools including heavy lathes, and vertical and horizontal boring machines
- plate heating furnace
- annealing furnace for complete vessels
- shot blasting equipment
- inspection equipment including X-ray machines and hydraulic test apparatus

108. Dished end forming would require equipment over and above this list (except for metal forming), and would, in any case, be kept separately. This production equipment would also require backing by a laboratory testing service.

109. It is considered that, generally, many British fabricators have not been generating enough new capital to purchase the new equipment they require. A common motive apparently behind the purchase of new equipment was that the equipment should be bought anyway and perhaps costs would come down after buying it. Large companies and members of groups of companies were more successful in obtaining capital for new equipment, not necessarily because of their higher profitability, but because of

their greater resources. Throughout the survey a strong impression was formed that British fabricators were well aware of the need for investment in new equipment, but that it was the capital and not the will to invest that was missing. Since profits had been frequently irregular it was, in a sense, praiseworthy that there was such good equipment to be found in some shops. The machinery of specialist British pressure vessel fabricators was not dissimilar to that of foreign competitors.

110. A more significant difference was apparent in shop lay-out. It was more difficult to decide where to put new machines and what overhead cranage was needed than to decide which new machines to buy. It has frequently been stated that some of Britain's fabrication shops are too old, having been built piecemeal over many years. This has resulted in a preponderance of small shops at individual fabrication sites rather than large multi-bay shops. When examples of the latter were seen it was often difficult to distinguish the activity in any one bay from that in another. More recently built shops both in the UK and on the Continent do afford examples of efficient layouts. Better through-put may generally be obtained through more efficient shop layout (where this exists), and/or through labour flexibility (where shops are physically separate one from another).

111. While a production line may not be feasible for pressure vessel fabrication, a definite sequence of events does take place and the shops should be laid out according to that sequence; plate cutting and preparation, plate rolling, sub-section welding, overall assembly, X-raying, annealing and testing. Machinery is most likely to fit in after the sub-section welding.

112. Since a crane is limited to one bay, the movement of workpieces from bay to bay is a slow operation usually carried out by bogie or occasionally by a crane in an end lateral bay. This means that long bays have all the advantages over short bays, and these advantages are absent in many British heavy fabrication shops. Ideally, one central bay is needed with the X-ray facility and furnace at one end. Two smaller side bays could serve for plate and component preparation and for rolling, at least for smaller sub-sections which could easily be manoeuvred into the main fabricating bay. This problem is complex but the above does indicate the disadvantages which exist in a number of the longer established fabricators.

Planning and control

113. Whether the shop be ideal or otherwise in its equipment and layout, the flow of materials cannot organise itself, and some planning must be made. The planning of a shop is basically the use of the variable factors to ensure maximum utility of the fixed facilities. The *fixed* facilities are the space and the machines, and the *variable* factors are the distribution of the work load, the distribution of the labour and the work balance.

114. The work balance assumes an ideal mix of vessels, towards which the sales department should always strive. Too wide a mix implies insufficient specialisation. Specialisation automatically leads to advantages in planning, thus giving increased through-put, experience and expertise. The mix is not so much a variable as an ideal which is never reached, and, for any given work load, the planning tools are the distribution of work and labour.

115. In the section under Personnel above it was noted that Britain's fabricators already had a serious inflexibility in the labour force which virtually removed one of the variables. No amount of computer planning about where to put the work could make up for this fundamental burden that the British industry suffered in comparison with its European competitors.

116. With or without a change in labour flexibility, production must be planned and controlled. The ineffectiveness of the methods used was demonstrated during the 1966 period when so very many deliveries were late. With the shortage of orders in 1967 delivery control was easier, and indeed most fabricators appeared to have made attempts to improve their methods. It is, therefore, to be hoped that the results of these efforts will be shown during a future period of high demand.

117. The ideally planned shop would have 100% full loading of all machines and men, and vessels in a shop would always be in some processing operation; from this it would follow that space was fully utilised.

118. The provision of full employment of the labour force would not be difficult, provided that the conditions necessary for flexibility were fulfilled. Machines presented more difficult problems, but since welding was such a crucial part of vessel manufacture at least these machines should be nearly fully used. Welding was usually the critical point in the production of a vessel, and the other operations can be considered as serving welding. A larger margin of spare capacity could, therefore, be anticipated in these other operations.

119. That considerable study of these problems is necessary was shown by the low proportion of actual working time during the production of a vessel. Estimations of the percentages involved varied from between 25% to 40%. This implied that for more than half its time in the factory (during working hours) a vessel was not receiving an added value input and was simply taking up space. As most work in the UK was one-shift, the percentage of *total* time during which the vessels were worked upon was made even less, e.g. 30% of work-time during one eight-hour shift represented 10% of total time during any twenty-four hour period. As the vessels occupied space during non-working hours the fixed overheads cost element in the manufacture of vessels was likely to be greater in the UK than abroad. It would be an interesting guide to fabricators if they provided themselves with more precise figures on the real proportion of working time. This would provide an excellent guide to good planning. Figures in the order of 75% on working hours would be ideally acceptable. Clearly the preponderance of single shift working also affected the overall economics.

120. A system of planning which shows the pre-production path and the progress of a vessel with regard to its plan is essential. This could act as a reassurance to the customer, both before and during production, that delivery would be held, and would be an important sales point. The types of planning and control procedures in mind here are PERT, CPM, Measured Day Work schemes etc. as well as better communications between sales and production divisions within individual companies. Furthermore, a reliable system of informing the customers of progress would probably reduce the number of visits from expeditors, who were not particularly welcome as visitors.

121. In planning, any design modification could be a serious disturbing factor as it meant that plans had to be changed as production proceeded. This was discussed under the section on Design in the present Annex.

Research and development

122. The majority of research and development in the pressure vessel industry was directed towards new welding techniques and the welding of new materials. Only fabricators with total staffs of several hundred could normally afford a proper research staff of one or two metallurgists and their assistants. Most of this welding work was directly or indirectly connected with the British Welding Research Association, and often consisted of developing a new BWRA process to the production stage.

123. Companies belonging to groups of companies often shared centralised research and development facilities which were invariably wider in scope than the facilities of a separate company. Research and development departments, when run as separate facilities as in the case of groups of companies, did run the risk of being cut off from design and production. In planning their activities, the basic function of research and development departments should not be lost sight of (viz. providing the design team with up-to-date information on materials; welding and stress analysing techniques) so that the design of pressure vessels could be continuously advanced.

124. The volume of research and development in Britain into materials and welding techniques is believed to be comparable or better than other European countries; but British management policy, which tends to regard all aspects of research and development as being of necessity subject to commercial secrecy, may be questioned. This is contrary to general American practice, and more exchange of information on research and development activities could take place to the benefit of the British industry as a whole.

Trade associations

125. The most important trade association specifically for pressure vessels, tanks and heat exchangers is the Tank and Industrial Plant Association (TIPA). The expressed aim of TIPA is to improve the products of its members. Its members must be fabricators of high quality (though not necessarily Class I) in carbon steel of ⅜" thickness and over, or any thickness of stainless steel.

126. Although TIPA's expressed aim appears to be of a technical nature, and although it runs a service of distributing journal articles to its members, its main activities are commercial. It collects from its members extremely valuable statistics and, together with case histories of, for example, foreign competition, it is building up a store of highly significant data. As a forum for pressure vessel builders and for co-ordinating representations to Government bodies TIPA proves useful to many, though perhaps not all, its members.

127. The degree of interest shown in TIPA by those of its members met during the survey varied quite considerably and, in general, it was the large fabricators that showed the most interest.

128. A weakness of TIPA was believed to be the incompleteness of its membership. There were several important stainless steel specialist fabricators who were not members. These fabricators were likely to belong to the British Chemical Plant Manufacturers Association which, although it had a much wider scope than TIPA, included pressure vessels in the 'definition' of its area of interest. It is inevitably a cause for unease that members of the pressure vessel industry are divided between two organisations which, although they have a certain liaison, operated in the main quite independently.

129. Since TIPA is the specialist organisation, it is considered that all significant pressure vessel fabricators should belong to it, though there should be no reason to discourage membership of other organisations as well. With a complete membership TIPA's work would be even more valuable. Other areas where TIPA could make an important contribution were in publicising the industry and in gathering marketing information, and both these points have been briefly discussed in the earlier section on Sales and Marketing in this Annex.

130. It has been one of the features of this survey that the pressure vessel industry is ill-defined. TIPA could eliminate this by publishing a booklet, say the 'British Pressure Vessel, Tank and Heat-Exchanger Manual'. It is believed that rationalisation should be sought by specialisation rather than by diversification; thus even a fabricator should be given one 'class' only, unless he was equipped with separate production facilities. The Manual should give the production range of each company, stating its particular equipment and expertise, and even give an indication of the capacity of the company.

131. Such a manual, regularly up-dated and well presented could be an exceedingly useful reference for both home and foreign pressure vessel users. The up-dating and distribution could be under the care of TIPA and any member would have the right to add a new name to the distribution list, which should be as wide as possible. Such trade manuals have been produced by other organisations, for example the British Gear Manufacturers' Association has published a concise booklet listing each manufacturer with his associated range, together with an index.

132. The other area in which TIPA might expand its activities is in gathering market information. In the section on Sales and Marketing the type of information that is needed has been indicated. It is perfectly logical that such information should be gathered on a group basis since the effort involved would be too much for any one company and, in any case, the information required by the different members would be essentially similar in nature. Subscription to this 'Market Information Service' could be an optional extra, possibly with individual company's contributions varying proportionally to their pressure vessel capacity, rather than through a general increase in membership fees. Since this work was highly specialised, requiring a technical and commercial knowledge together with the ability to penetrate foreign countries which did not always use English as a commercial language, TIPA may need to take on specialised staff or sub-contract the work.

ANNEX D

UK supply: design standards and inspection of pressure vessels: their economic implications

1. Pressure vessel design standards often make only slight reference to inspection procedures and, indeed, inspection considerations do not usually have serious effects on design except when accessibility of testing equipment is considered. The standards for design and for inspection have a different emphasis: good design is aimed at producing a pressure vessel just good enough for the application, while inspection is aimed at making sure the vessel is at least good enough. Design is naturally progressive and inspection naturally conservative; their interdependence and economic implications are considered in this annex, as well as technical aspects of the standards.

The function of design standards

2. The standards to which pressure vessels are designed have two main functions:

to ensure that certain minimum safety requirements are adhered to;

to facilitate the design of vessels by indicating good practice for those individual design requirements not directly connected with safety.

3. The safety requirement is the easier of the two functions to introduce into a standard. The basic formulae for wall thickness, the welding procedures (mainly edge preparation) and weld factors, the compensation around openings and testing procedures usually ensure a certain minimum degree of safety. All these requirements may be readily expressed in technical terms, and this facilitates the overall expression of the safety requirement. However, this does not prevent these basic requirements from causing more disagreement in design standard preparation than any other aspect.

4. The second function of a design standard is to provide 'design detail' which involves a deeper technical knowledge than the straightforward safety requirement. Engineers with long experience of design are suitable for use in the preparation of design details, but, because the details are mainly in the single area of mechanical engineering they are produced without the prolonged arguments associated with safety requirements—provided adequate numbers of engineers are brought to bear.

5. To fulfil successfully the two functions, a good pressure vessel design standard must be:

wide in scope, covering as many design contingencies as possible and answering almost every query that could be posed by a designer;

modern, reflecting the best modern practice and not hindering the application of new ideas when they are worthy.

Preparation of design standards and inspection procedures

6. A design standard may only contain proven methods. It is a fundamental paradox of a standard that, if it must be followed, new methods cannot be tried, proven and therefore entered into the standard. Different countries bave developed different methods of enforcing their design standards to ensure that safety requirements are followed. The legally enforced design standard is the most common system, but this does lead to a certain degree of inflexibility due to the laborious work involved in updating details incorporated in, or referred to, by legislation.

7. In looking for a system for the preparation and administration of design standards it is important to ask what properties of the system are desirable. These might be summed up as follows:

a good design standard must be produced, fulfilling the requirements for safety and for good detail design;

it must be possible to try out new design concepts, and if proven successful, make their rapid inclusion into the standard;

the enforcement of the standard should involve expert and impartial inspection methods;

the whole system, both from the inspection and the standard modification points of view, must be simple and quick-acting.

8. Inspection in the UK is carried out by representatives from the major insurance and registration offices as well as from the engineering contractor who may be purchasing the vessel, and from the final user. Production inspection must also be carried out by the inspection staff of the fabricator. It is of importance to note that none of these inspection bodies are co-ordinated by a single body although they usually have representation on the BSI committee which prepares the design standard. Furthermore, the inspection standard of every inspection body is prepared by that body and is usually different from that of any other body. Much of the interpretation is the responsibility of the individual inspectors. The degree of completeness and of the flexibility of the various inspection standards also differ.

9. The above position leads to the following effects:

multiplicity of inspection;

disagreement between inspectors from different organisations, and even from the same organisation;

an apparent variation in stringency;

resistance to new design standards and design techniques.

10. The experience gained during inspection often has a direct bearing on design standard preparation; that is, there should be a feed-back from the former to the latter. If in the preparation of design standards a new idea presents itself, some co-operation with the inspection organisations to allow a trial is necessary. The continuing interchange between preparation of design standards and inspection is thus essential. It may also be feasible to consider the preparation of inspection standards in terms of sizes of inclusions, laminations etc., although a substantial amount of work may be required to provide accurate experience upon which to base such standards.

Comparison of the scope of four leading design standards

11. A consideration of the following points leads to an appreciation of the scope of design standards:

(i) materials accepted within a broad range of definition;
(ii) specific materials accepted within the general definition;
(iii) pressure range;
(iv) temperature range;
(v) consideration given to fatigue loading;
(vi) whether or not thick-walled vessels are included;
(vii) whether or not jacketed vessels are included.

12. The list is not complete, but will serve in comparing two British, one American and one German design standard.

13. The materials covered by the standards (point (i)) are listed below:

Standard	Low carbon mild steel	High carbon and alloy steel	Stainless steel	Aluminium and its alloys	Clad steels	Copper and its alloys	Reactive metals
ASME	Yes	Yes	Yes	Yes	Yes	Yes	No
BS 1500	Yes	No	Yes	Yes	No	No	No
BS 1515	Yes	Yes	No	No	No	No	No
TUV	Yes	Yes	Yes	Yes*	Yes	Yes*	No

* AD Merkblätter – W 6 to be published

14. Point (ii) refers to the possibility of accepting other than listed steels (i.e. foreign steels, new steels, etc.) and is allowed for by BS 1515 and TUV only (see Table D1), although the mechanism for acceptance of such steels is not yet published in Great Britain.

15. Points (iii) to (vii), judging the scope of the standards, are:

Standard	Negative as well as positive pressure	Low as well as normal and high temp.	Fatigue	Thick walled vessels	Jacketed vessels
ASME	Yes*	Yes	No	Yes	No
BS 1500	Yes	Yes	No	No	Yes
BS 1515	No	Yes	Yes	No	No
TUV	Yes	Yes	No	Yes	No

* ASME excludes pressures of ±15 psig and greater than 3,000 psig, thus 'vacuum' vessels are excluded without a further pressure applied externally

16. In respect of the detail of the standards (enabling the design and the drawings of a pressure vessel to be prepared easily) including their style, extra comments, and intangibles tbat may only be appreciated by using the standards as a design tool for a considerable period of time, the opinions expressed during the survey may be summarised as:

ASME is thorough, practical and easy to design to;

BS do not enter into sufficient detail, though they are technically better than ASME;

the TUV standard, though well detailed, is lacking in drawings for quick and easy reference.

'Class' qualification tests for fabricators

17. If a design standard refers to a class of pressure vessel, it might be expected that some qualifying test be mentioned by which a fabricator may be classed.

18. In the two British standards, no system is mentioned although BS 1500 makes reference to three classes of vessel and BS 1515 to one class which, by implication, is the highest. Furthermore the term 'Class' is used to class fabricators as Class I or Class II according to a Lloyds' definition and testing procedure, aimed mainly at the welders and welding apparatus, but having no direct bearing on the 'classes' in BS 1500 or BS 1515.

19. The ASME Section VIII makes no reference to a class of vessel or to a method of qualifying fabricators. However, the necessary inspection and manufacturers' stamps, issued by the American Society of Mechanical Engineers, can be withheld by the Society 'in its absolute discretion'.

20. The TUV does have a well-developed inspection system. All would-be fabricators to the TUV standard are inspected and their welders tested. There is no 'class' of vessel as such, but a new fabricator is only awarded a weld factor of 0·8 instead of 1·0, until a vessel built by him to the standard is proved in service. Such a system is restrictive to worthy newcomers.

21. Qualifying tests for fabricators should include inspection of the following of their facilities:

welding apparatus;
rolling and plate edge preparation apparatus;
testing equipment, especially X-ray;
welders' skills;
designers' ability (measured by qualifications and experience).

Comparison of the technical factors in leading design standards

22. Every technical aspect of the different design standards is not considered here. However, by concentrating on the means of calculating the design stress the relative technical standing of the leading pressure vessel standards may be illustrated.

23. The design stress is found by taking one or more measured stress properties of the material of construction and dividing by some factor of safety. There is also a joint factor which further reduces the design stress according to the quality of the weld. For fully X-rayed welds in approved materials the value of the weld factor is 1·0 in the five standards studied below except for BS 1500 where it is 0·95.

24. The term factor of safety has sometimes been replaced by the term factor of ignorance. It is indeed the philosophy of the factor of safety that unknown effects are taken care of by a margin between the calculated working stress and another, higher, stress measuring strength. Since the degree of ignorance in stress calculations welding and related phenomena is probably less today than, say, two decades ago, a decrease in the factor of safety could be expected over the years. If a standard is of high technical calibre, one would then expect a lower factor of safety and a higher design stress for a given steel, always provided that calculation and inspection methods were sufficiently sophisticated. Technical standing can also be measured by the stress property to be taken as the strength defining property, e.g. yield stress, ultimate tensile strength etc.

25. Taking the two British Standards, the ASME, the TUV and the proposed ISO standard, Table D(2) shows which properties are used in the various standards, as well as the values of the factor of safety. The table is with reference to information actually stated in the standard, and the principle in each standard is to take the lowest design stress value given when more than one means of calculating the design stress is indicated.

26. In Table D(2) the factors of safety vary particularly with regard to the ultimate tensile strength (UTS). The lower the safety factor the higher is the design stress and thinner the wall, so those standards accepting a low factor may be considered more progressive. When the safety factor for the UTS is large, the UTS becomes the controlling property rather than the yield stress (YS). Generally ASME and BS 1500 are UTS controlled, and lead to low design stresses. BS 1515 and ISO tend to be YS controlled, and TUV is always YS controlled. ASME and BS 1500 may be considered conservative, both for the basis for calculation and for the low level of design stress thus calculated.

27. Most standards bring in creep stress as a check at the operating temperature. The only one with any appreciably different approach is TUV which, in considering the 1%/100,000 hour creep stress at 15°C above operating temperature, makes allowance for unforseen temperature variations acting on a steel with high temperature-dependent creep properties. ISO applies a 1·6 safety factor and BS 1515 and TUV apply a 1·5 safety factor to the creep-to-rupture stress at operating temperature. Since onset of deformation is more important than final rupture as a failure criterion there is a case for only considering the former stress.

28. The minor differences arising from these high temperature checks are not crucial, whereas the UTS versus YS criterion affects most temperatures and provides the design stress for the majority of temperature cases which are below creep effects.

29. Since general plastic deformation is the effect which determines the onset of tensile failure, virtually all informed opinion has recognised that yield stress is the relevant property in defining the strength of the steel, and not the ultimate tensile strength. Consideration should also be given, in any design, to the problems of fatigue and fast fracture.

30. The design standard giving the highest design stress depends upon the material used, e.g. carbon steels, stainless steels or non-ferrous materials, and there are temperature cross-over points where, for example, the ASME standard gives a higher stress than the TUV standard in certain materials. Nevertheless an important comparison of YS with UTS may be made with carbon steels at room temperature, representing as it does the majority of pressure vessels.

TABLE D(2)

Stress properties and safety factors to be taken for design stress calculation in various design standards

Standard	R_{20}	R_t	E_t	S_R	S_c	S_c*
ASME	4·0	4·0	1·6		1·0	
BS 1500	4·0	(1)				
BS 1515	2·35		1·5	1·5	1·0	
TUV			1·5(2)	1·5(2)		1·0
ISO(3)	2·7		1·6(4)	1·6	1·0	

Notes: R_{20} minimum ultimate tensile strength at room temperature

R_t minimum ultimate tensile strength at operating temperature

E_t the minimum yield stress at operating temperature or, if yield point not clearly defined, the 0·2% proof stress at operating temperature

S_R the average stress for rupture after 100,000 hours at operating temperature

S_0 the average stress for 1% creep in 100,000 hours at operating temperature

S_c* the average stress for 1% creep in 100,000 hours at operating temperature plus 15°C

(1) Although not stated in the standard, it appears that BS 1500 follows ASME in design stress calculation at elevated temperatures

(2) This factor increased to 1·8 for steels not certified according to DIN 50 049

(3) Figures taken from the Draft Boiler Code

(4) For temperatures less than 250°C, the properties are to be taken as those at 250°C (except R_{20})

31. In Table D(3) the YS and UTS of several carbon constructional steels are listed. The design stress calculation is then made for every steel using ASME, BS 1500 (with a weld factor of 0·95), BS1515, ISO, and TUV standards. Three groups of steels are taken and important conclusions can be drawn both about the standards chosen and the steel. In each group the four steels chosen are from Great Britain, France, Germany and the USA respectively; and the groups relate to:

Group 1 long established low strength constructional steels, still the most commonly used type in Great Britain;

Group 2 steels in existence for over four years and used in good modern practice;

Group 3 quenched and tempered steels now available for constructional purposes but not yet frequently used for pressure vessels.

From the figures in Table D(3) the following comments may be made:

BS 1500 gives the lowest design stress in every case;

ASME gives the second lowest design stress in every case;

BS 1515 and (except in one marginal case) ISO are YS controlled in the group 1 steels, but become UTS controlled in both group 2 and group 3 steels;

TUV gives the highest design stress every time, which is equalled only by BS 1515 on the YS controlled group 1 steels;

BS 1500 and ASME are UTS controlled by a *large* margin in every case, the margin being largest in group 3 steels.

TABLE D(3)

Design stress at room temperature of various steels by different design standards

The design stress to be taken is italicised,
R_{20}=UTS at room temperature: E_{20}=YS at room temperature.

STRESS STEEL	PROPERTY		ASME		BS 1500		BS 1515		ISO		TUV
	R_{20}	E_{20}	$R_{20}/4$	$E_{20}/1{\cdot}6$	As ASME but WF of 0·95		$R_{20}/2{\cdot}35$	$E_{20}/1{\cdot}5$	$R_{20}/2{\cdot}7$	$E_{20}/1{\cdot}6$	$E_{20}/1{\cdot}5$
1501–151 26B	26	14·8	*6·5*	9·25	*6·2*	8·8	11·1	*9·9*	9·65	*9·25*	*9·9*
GAPAVE 121 A42	26·8	15·6	*6·7*	9·75	*6·4*	9·25	11·4	*10·4*	9·9	*9·75*	*10·4*
DIN 17155 H. II	25·9	15·6	*6·5*	9·75	*6·2*	9·25	11·0	*10·4*	*9·6*	9·75	*10·4*
A 285 Gr C	24·6	13·4	*6·15*	8·4	*5·85*	8·0	11·5	*8·9*	9·1	*8·4*	*8·9*
DUCOL W30	38·0	30·0	*9·5*	18·7	*9·0*	17·8	*16·2*	20·0	*14·1*	18·7	*20·0*
Creuselso 38	34·9	24·1	*8·7*	15·1	*8·25*	14·35	*14·9*	16·1	*12·9*	15·1	*16·1*
FB 50	31·7	22·8	*7·9*	14·2	*7·5*	13·5	*13·5*	15·2	*11·7*	14·2	*15·2*
EXTEN 60	35·7	26·8	*8·9*	16·8	*8·45*	16·0	*15·2*	17·9	*13·2*	16·8	*17·9*
LOYCON QT	47·0	42·0	*11·7*	26·3	*11·1*	25·0	*20·0*	28·0	*17·4*	26·3	*28·0*
80 HLES	47·7	41·1	*11·9*	25·7	*11·3*	25·4	*20·3*	27·4	*17·7*	25·7	*27·4*
RHB 65	47·5	41·2	11·9	25·8	*11·3*	25·45	*20·2*	27·5	*17·6*	25·8	*27·5*
JALLOY S.90	44·6	41·4	*11·15*	25·9	*10·6*	25·6	*18·0*	27·6	*16·5*	25·9	*27·6*

32. When the strength of steels is improved, it is a phenomenon of nature that the yield strength (the most accurate guide to real strength) increases proportionately more than the UTS; hence the continued increase in YS/UTS ratios. This explains the change-over from YS to UTS control in BS 1515 and ISO as steel strength increases.

33. The stronger steels are more expensive per ton, and for them to be economic the strength (as measured by the acceptable design stress) must increase by a greater proportion than the price per ton. Only by making use of a yield strength based design stress is this condition fulfilled. The result is that the TUV standard most often renders the high strength steels economically interesting. Thus the advantages offered by the TUV standard, considerable for low strength steels, become even more important for high strength steels to the point that only the TUV standard enables these steels to be used economically.

34. For example, on BS1501–151–26B, TUV shows an advantage of 52% over ASME but gives the same design stress as BS 1515. On Loycon QT, TUV shows an advantage of 140% over ASME, thus enabling a wall thickness to be used with this material only 2/5th that prescribed by ASME, while the advantage is 40% over BS1515.

35. There is no doubt that the TUV standard leads to cheaper vessels. Usually competition between fabricators is for a vessel with the design standard specified. But when internationally operating contractors are about to build in a country where the standard is not specified they are free to choose the most economical standard, usually the TUV, and, not unnaturally, German fabricators are more likely to be considered for tender. Quite apart from this market aspect, the BS 1500 and 1515 are old-fashioned in considering the UTS, and are hindering technical innovation, particularly the use of high quality steels such as those which are quenched and tempered. Those interviewed on the survey felt that many other details of these standards needed clarifying.

36. Although a safety factor on UTS has not been included for the TUV standard in the Table D(3), there would appear to be certain limiting values for YS and for the YS/UTS ratio. Thus AD Specification B.10—thick-walled hollow cylinders—requires that the value used in the calculation for the yield point, relative to 20°C, may not exceed 0·7 (R_{20}) for non-heat-treated steels and 0·8 (R_{20}) for heat-treated steels. In effect, these factors impose a limiting design stress of $R_{20}/2{\cdot}14$ and $R_{20}/1{\cdot}88$ respectively. Furthermore, TUV would appear not to accept steels for which the E/R ratio falls outside the following limits; as the heat treatment may be suspected as being unsatisfactory:

Type of steel	*E/R ratio*
Normalised steels	0·50–0·75
Fine grain steels	0·75–0·85
Quenched and tempered steels	0·70–0·85
High yield steels (static loads)	0·80–0·93
High yield steels (fatigue loads)	0·70–0·75

It is thus possible that UTS is considered when AD Specifications are used in pressure vessel design. However, the UTS factor (if it is about R/2·0) would make no difference to the superior position of the TUV standard, in respect of design stresses, for all the steels considered in the Table.

37. The following suggestions are made in respect of BS:

that BS 1500 be discontinued;

that BS 1515 be widened in scope to cover all the points left uncovered by the removal of BS 1500 and at least all the materials and types of vessels described under Scope (see page 213);

that BS 1515 cease to consider ultimate tensile strength in design strength calculations;

that BS 1515 introduce a 'class' of vessel for each material and specify Classes I and II with reference to radiography, finish, dimensional accuracy and other criteria which, when passed at a lower standard, lead to a reduction in cost. Tbe reduction in cost could include the use of older or less sophisticated machinery;

that more BS be introduced, similar to BS 1966—Domed Ends, to cover the specifications of components for pressure vessels, notably for forged parts—flanges and nozzles;

that the materials standards for steel plate and steel for forgings be rapidly clarified on an international basis;

that the International Standards Organisation be encouraged to accept a 1·5 safety factor based on yield stress, and to cease consideration of the ultimate tensile strengtb, with consequent review of testing procedure;

that in design stress calculations clear indications of fatigue considerations be presented;

that brittle failure considerations be introduced as a safety check in design calculations.

ANNEX E

Qualitative review of UK demand sectors

1. This annex is based mainly on the qualitative information obtained during an interview programme with final users and contractors. A review of the significant pressure vessel usage and of the likely changes in pressure vessel requirements is given for each of the sectors studied.

Primary demand sectors

Mineral oil refining

SIC (1958): MLH 262 AND 263

2. Since 1950, oil consumption has been buoyant. Before this date the energy needs of the British economy were mainly met by coal. As late as 1957 the share of oil in the total UK energy supply was only 15%. In 1967, it was about 40% and will remain at about this level up to 1970. There has been a major increase in total British refining capacity, which has risen from about 58 million tons in 1963 to about 88 million tons at the end of 1967. It is believed that this capacity will be adequate to meet domestic demand until 1970.

3. The main products of mineral oil refining are, in order of importance: fuel oil, diesel oil, motor spirit, petrochemical feedstock including 'light petroleum distillate', kerosene, bitumen, lubricating oils, butane and propane and wide-cut gasoline. Fuel oil represented 43% of the total in 1966. All these products are obtained from crude and process oils other than distillation benzines. Continuous production techniques are almost exclusively used, batch processes being used to a very small extent. The present technical trend is mainly towards larger units of production based on higher operating pressures and temperatures.

4. Contractors share of total procurement of new pressure vessels is very high and replacement demand is insignificant in this sector.

5. The suggested 'vessel to total investment in plant' percentage in the NEDO process plant report averages out at about 22·5% with pressure vessels representing 9·0%, heat exchangers 8·0% and tanks 5·5%. However, the following figures drawn from two actual projects would suggest this percentage is about 19%:

(a) oil refinery (total investment in plant and machinery £2·4 M) pressure vessel and heat exchanger content 12·9%;

(b) oil refinery (total investment in plant and machinery £44·0 M) pressure vessel and heat exchanger content 14·8%.

These differences probably arise from the definition used for vessels in this study, as tanks at least are not included in these figures.

6. In the two oil refineries quoted above the sources of supply of pressure vessels showed the following breakdowns:

Refinery	*UK share*	*Foreign share*
(a)	33%	67%
(b)	0	100%

7. Three interesting groups of pressure vessels are worth citing:

distillation columns:

pressures typically 200–250 psig

dimensions: 7–14 ft. diameter, up to 200 ft. high

temperature: up to about 200°C

although big, and indeed becoming bigger, these vessels are relatively simple and are usually built in carbon and low alloy steel;

platformer:

in which low octane naphtha is partially converted into petrol

pressure: 400–500 psig

dimensions: 15 ft diameter, 30–45 ft high

temperature: up to 550°C

the pressure is not high but the temperature does call for more specialised materials and construction;

hydrocracker:

a relatively new element in refineries and a basic element of the refinery of the future (i.e. the 'all hydrogen' refinery)

pressures: 1,500 psig increasing to 2,000 psig

dimensions: 18 ft diameter, 60 ft long, wall thickness up to 8 in

temperature: around 400°C

the future importance of special alloy vessels for this function in refineries cannot be over-emphasised and only the German, Japanese and American fabrication industries were, prior to 1967, considered capable of building such vessels. The American influence is diminishing as their labour costs are high, but Japanese competition, including European delivery, is now serious for these vessels. In addition to these high pressure vessels, the operation of hydrocracking also requires large vacuum vessels.

8. Price differentials were found to be considerable during 1966, ranging from 10–30% between UK and foreign fabricators. Delivery is the main criterion when choice of fabricator is made, as price loses its importance when price differentials are only 5–10%. The comment was generally made that it was desirable for British fabricators to quote realistic delivery dates. Moreover, there was a tendency to state that delivery delays were more important when they occurred with large vessels, where even one day delays could be critical. All the oil companies interviewed commented, in 1967, that UK fabricators should improve further their quotations and honouring of delivery dates.

9. Both UK and foreign fabricators design well. The normal procedure is for the oil company to draw up a specification while the detailed drawing is left to the fabricator. Difficulties are rarely encountered in locating fabricators to design to foreign standards, either in Britain or abroad.

10. There appears to be no possibility of standardising pressure vessels from any point of view (eg dimensions, materials). The main reason for this is that vessels are tailor-made for every new project. Even when existing ones are replaced, larger ones normally take their place. Some standardisation is done however on storage tanks(eg LPG). It is of interest to note that one company interviewed had standardised in order to shorten delivery dates; the price saving was insignificant.

11. The number of invitations to tender sent out can be as low as three to four. In the case of projects abroad, one company interviewed sent out six invitations, three within the UK and three abroad. All companies had some kind of list of fabricators who met their own particular requirements. Invitations to tender are sent out on the basis of these lists which are under constant revision. Only one company commented on the speed with which the fabricator submitted his quotation.

Future pressure vessel demand in mineral oil refining

12. It is considered that operating pressures, temperatures and unit sizes will remain as they are at present with, however, a tendency to rise within the next five years. One company predicted a trend to thicker-shelled vessels rather than thinner-shelled ones built with high tensile strength steels.

13. All the companies interviewed had been affected by the closing of the Suez Canal, which had reduced their liquid reserves and created a tight money situation. This meant a levelling off, even in projects already under way, and this situation was expected to remain the same until the end of 1968.

14. The need for thick-walled massive pressure vessels for all-hydrogen refineries is one major technological growth area in which the UK should become expert (a second such area is in the handling and storage of LNG).

15. Any forecast of future investment in oil refinery capacity in the United Kingdom must take into account the likely future energy pattern in the country. The discovery of natural gas in the North Sea combined with the growing competitiveness of nuclear-based power has changed previous plans to a drastic extent. The UK will certainly move from being a two-fuel to a four-fuel energy economy and the latest statements (November 1967) of the Ministry of Power forecast a situation along the following lines:

	M. tons coal equivalent			
	1957 (actual)	1966 (actual)	1970	1975
Coal	212·9	174·7	152*	120*
Oil	36·7	111·7	125	145
Nuclear and hydro	1·7	10·2	16	35
Natural gas	—	1·1	17	50
Total primary fuel use	251·3	297·7	310	350

* Exports of coal estimated at about 3 million tons in 1970 and 2 million tons in 1975

16. The reduction in the position of coal is the most evident factor, but the forecast growth in the consumption of oil from 1966 to 1975 (3% per year) is far slower than from 1957 to 1966 (13% per year). This is due mainly to the impact of natural gas and nuclear power and the former's share may be underestimated. There are many other

imponderables such as the use of natural gas as a chemical feedstock which could again adversely affect the future demand for naphtha from the refineries. The price of natural gas is, of course, the determining factor.

17. The combination of these factors, together with the massive investment programme in new refinery capacity between 1963–1967, would suggest that a conservative estimate of future pressure vessel demand should be made in this sector.

Town gas

SIC (1958): MLH 601

18. The Gas Council is made up of the central body with 12 Area Gas Boards each of which has a large measure of financial and operational responsibility. Since the enactment of the Gas Act 1965, the Gas Council is now both a co-ordinating and a trading body.

19. For many years the chief method of production was by carbonising coal, but in recent years oil-based production has expanded markedly. Coal consumption at gasworks fell from 25 million tons in 1958 to 18 million tons in 1965: in the same period oil consumption increased from ¾ million tons to 2½ million tons. Purchases of gas from the petroleum industry have also increased so that by 1965 nearly one-third of the town gas available was derived from petroleum. The gas industry's purchases of coke-oven gas have fallen slightly throughout the period 1958 to 1965 and account for a diminishing proportion of the expanding availability of town gas.

20. In 1965 sales of town gas were about equally divided between domestic and commercial or industrial uses. In recent years total sales have increased at about 8% p.a. and a high rate of growth is expected in the next decade.

21. There are further changes in the gas supply structure with the increased expenditure on a natural gas transmission system (new trunk pipe mains) originally using imported LNG but based mainly on the exploitation of the North Sea natural gas reserves in the future. The impact of the North Sea gas is liable to be so important that even the steam-reformer plants that have been built in recent years for oil-based production will now cease to be built. Thus both basic methods of manufacturing gas will no longer require new plant and the Gas Board will become orientated to gas distribution, with manufacture of gas for purification and enrichment as a secondary activity. There will obviously be some replacement market for pressure vessels in the existing plant but very small when compared with the previous massive investment programme.

22. Complete plants for gasification are normally procured through contractors. Vessel content in one gas reformer plant was 9·6% in terms of total value of equipment procured. Other projects for oil gasification suggest a higher proportion reaching 20·0%.

23. Other principal requirements for pressure vessels have been high pressure gas storage vessels and LPG storage vessels. One area board interviewed had purchased an average of 15 high pressure storage vessels a year at an average cost per unit of £32,000 over the period 1961–66, while butane bullets had averaged out to 3/year at £11,000 per unit. High pressure gas holders had only become economic with the widespread

adoption of oil gasification plants as they eliminated some compressors and give more flexibility than the atmospheric types. With the introduction of BS 1515, prices had dropped considerably as the use of the ASME design standard would increase costs by 20%. Vessels are normally as follows:

> 12 ft in diameter and 192 ft in length with a working pressure of 350 psig. All vessels are in mild steel with grade 32A—ie improved tensile strength—the most popular;
>
> butane bullets are of two types: 100 ton capacity with a 12 ft diameter and a 70–80 ft length and 150 ton capacity with a diameter of 15 ft and a length of 90 ft. The maximum working pressure is 210 psig.

24. With regard to high pressure gas holders, the design work including the choice of material is left to the fabricator who is given some orientation through brief specifications. The Area Gas Board interviewed had already ordered 40 vessels from the same manufacturer, so that the latter offered virtually a standard design. All inspection for this Gas Board is carried out by an insurance company which is paid a special service fee to act as consultants throughout the fabrication and installation. Progress reports are provided.

Future pressure vessel demand in town gas

25. Changes in pressure vessel requirements will result from the present technical modifications taking place in the industry of which the most significant is the future vessel requirement for storage. Due to the advent of wire-wound reinforced concrete pressure vessels for gas storage a drop in demand for steel gas storage vessels might develop in the long term. High pressure holders are being calculated on a 40 year life basis. All additional storage capacity is likely to be of this type. Future needs for butane bullets is expected to be lower than that in the 1962–67 period.

Electricity generation

26. The generating boards have under construction a number of large conventional power stations (most of which have 4 × 500 MW units) and rather smaller sized nuclear stations. The latter are expected to become more impotant but there will continue to be scope for some new conventional stations. Peak production is taken up by a large number of coal-fired stations and by modern gas turbines.

27. Three types of pressure vessels may be mentioned:

> gas-cooled graphite-moderated nuclear reactor containment vessels are now site-built, concretereinforced structures in the UK; if however the UK decided to enter the pressurised or boiling water reactor market as is the practice in the USA, there would be an immediate market for thick vessels. The vessels used in the USA for this purpose are perhaps the thickest walled fabricated pressure vessels in the world. Their thickness often lies between 9″–13″;
>
> the vessels associated with the coolant (high pressure CO_2 in an AGR) of a nuclear reactor. Units for storage, vapourising and heat exchange at pressures up to 400 psig are encountered. Thicknesses rarely exceed 1″;
>
> vessels forming part of the boiler in a coal-fired station. Pressures are high for steam containing vessels, e.g. 2,400 psig and wall thickness usually greater than 1″. The most sophisticated vessel is the boiler drum which may be 6″ thick, 8 ft in diameter, weigh up to 400 tons and require fabrication in high strength steel.

Future pressure vessel demand in electricity generation

28. One possible change has been indicated already, a change back from concrete to steel for nuclear containment vessels. Otherwise vessels will remain of the same type but with the continued increase in size and pressure, and more use of high strength materials may be anticipated.

Heavy organic chemicals

SIC (1958): MLH 271–3 parts

29. Heavy organic chemicals are mainly high-tonnage production intermediary products leading to the production of final products such as plastics, synthetic fibres and detergents. The following are worth mentioning as leading examples: ethylene, propylene, butadiene, formaldehyde, propyl alcohols, ethylene oxide, acetone, synthetic phenol and phthalates and carhosylic acids (in particular acetic acid.)

30. Since 1945 the raw material of the heavy organic chemical industry has changed from coal tar, molasses (alcohol played a key role as the principal product from the fermentation of molasses) and calcium carbide, etc., towards refinery products as a raw material, in particular light petroleum distillate (LPD). This has developed to the point that the expression 'petro-chemical industry' is virtually synonomous with 'heavy organic chemical industry'. The UK's petroleum and organic chemical industries are now closely associated with each other over many areas.

31. These changes have meant the introduction of continuous processes, high pressures, high temperatures and highly corrosive atmospheres. Pressure vessel requirements are stringent and continually advancing; while carbon steels have probably retained their average relative importance, copper has largely fallen out of use in favour of stainless steel.

32. A series of specimen projects are given below with a view to determining the proportion of vessels to total investment in plant and machinery:

(a) Esters plant (total investment in plant and machinery £287,000) overall vessel content 30% of value of equipment procured;

(b) Phthalic anhydride plant (total investment in plant and machinery £909,000) overall vessel content 17% of value of equipment procured;

(c) Ethylene dicloride plant (total investment in plant and machinery £445,000) overall vessel content 28% of value of equipment procured;

(d) Polyethylene plant (total investment in plant and machinery £5·8 M) overall vessel content 7% in terms of materials costs;

(e) Ethylene oxide (total investment in plant and machinery £4·0 M) overall vessel content 24% of value of equipment procured;

(f) Polymer, sulphuric acid and phosphates (total investment in plant and machinery £4·5 M) overall vessel content 28% of value of equipment procured;

33. The overall vessel contents would appear to vary widely but if the polyethylene plant is excluded, there is a range of 17–30%. There is an average plant duration of 10 years due to obsolescence.

34. This sector is (along with the refinery industry) a most important outlet for pressure vessels of all types but also of 'spectacular' vessels, i.e. very large, thick walled, special material vessels. For these vessels, which though small in number have a very high value, it was considered that the British pressure vessel industry could further improve its technical position so as to meet these special requirements more adequately.

35. The following characteristics have been drawn from a series of projects and show the wide range of vessels used:

(a) Esters plant

shell thickness	⅜ in average
operating pressure	35 psig (5 ft diameter)
fabrication materials	stainless and carbon steels

(b) Reactor hydrogenerator plant

weight	64 tons
shell thickness	1½ in
diameter	14 ft
overall length	33 ft 6 in
Reactor product separator	
shell thickness	1⅞ in
diameter	16 ft 6 in
overall length	45 ft
Heavy reactor	
shell thickness	2½ in
diameter	21 ft
overall length	30–40 ft

(c) Ethylene dichloride plant

weight	up to 47 tons
shell thickness	up to ⅞ in
operating pressure	full vacuum to 350 psig
fabrication material	carbon steel

(d) Polyethylene plant

weight	20–80 tons
shell thickness	¾″–8″ (hollow forgings)
operating pressure	up to 10,000 psig for the high pressure process

(e) Acetic acid

shell thickness	¼″–4″
fabrication material	85% special stainless steel, 15% copper

(f) Polymer, sulphuric acid and phosphates complex

weight	4–100 tons
shell thickness	$\frac{5}{16}$″–3″
operating pressure	10–30 psig (diameter 2–5 ft)
fabrication material	mild and stainless steels.

36. The stainless steel vessels are particularly important in the oxidation reaction. The most important characteristics of the vessels for this sector are the sophisticated materials required for adverse corrosion and temperature conditions (eg titanium-lined vessels). Shell thicknesses are rarely beyond 2 in as pressures remain lower than in some refining and inorganic chemistry processes.

37. The following data on the sources of supply are based on specimen projects quoted in paragraph 32:

	UK supply	*Foreign supply*
(a) Esters plant	91%	9%
(b) Phthalic anhydride plant	100%	0
(c) Ethylene dichloride plant	19%	81%
(d) Polyethylene plant	100%	0
(e) Acetic acid plant	80%	20%
(f) Polymer, sulphuric acid and phosphates complex	88%	12%
(g) Ethylene oxide plant	57%	43%
(h) Olefin plant	0	100%

38. On the whole, foreign price and delivery quotations proved to be about the same as those of UK companies. The differentials during 1965–6 had disappeared almost completely by 1967. The importance of technology, at least for the sophisticated vessels, is such that it may be the sole criteria of choice.

39. The number of invitations to tender per potential order may reach as many as sixteen. There is a tendency to send out an average of 5–6 invitations to tender for 'ordinary' vessels.

Future pressure vessel demand in heavy organic chemicals

40. As the instrumentation content of a chemical plant has increased over the past few years so the precentage of pressure vessel investment in plant and machinery has fallen. The trend will be towards larger vessels so the materials will have to be not only of high corrosion resistance but also of high strength; for example, high yield strength stainless steel should prove of great interest to this sector.

41. Investment in the future will be primarily in plants of very high tonnage which offer large economies of scale where the market is large enough to warrant these. Export markets are, therefore, essential and this, together with the commercial and technical reasons for combining chemical processing and refinery operations, will tend to concentrate the future investment into a smaller number of highly integrated companies.

Fertilizers and pesticides

SIC (1958): MLH 217–2

42. These two product groupings are often classified together as their market is similar and indeed they can be combined for distribution. However, from the point of view of pressure vessel usage they should be completely separated as the processes involved are entirely different.

43. The three main fertilizer nutrients are phosphate, nitrogen and potash and depending on whether a fertilizer introduces one or more nutrient it is called straight or compound. Pressures for the final production of fertilizers are quite low (less than 100 psig), with the important exception of the manufacture of urea which in the Stamicarbon process (for example) requires pressures of 3,000 psig and temperatures of

200°C. One raw material for fertilizer production (ammonia) also requires in certain processes high pressures (up to 5,000 psig). Sulphuric acid and nitric acid do not require such high pressures. Throughout the final fertilizer manufacture, stainless steel is commonly used to meet corrosive conditions.

44. Pesticides cover insecticides, pesticides, fungicides, herbicides and allied products. Of these, herbicides are currently the largest production, followed by insecticides. Herbicides have shown the highest growth rate, more than doubling during the 1962–66 period. In 1966 they represented 66% of total sales value for all pesticides compared to a 40% share in 1962. The growth rate for pesticides in the UK is about 8% per annum.

45. The ratio of vessel purchases to total equipment investment is about 28%. Replacement demand is less than 1% of vessel procurement. Examples of percentages of vessel costs in plant and machinery costs are given below:

(a) Ammonia plant (material costs £1·31 M) vessel content: 19·7%. (Shell thickness 80 mm, weight 104 tons, quenched and tempered steel.)

(b) Urea plant (material costs £0·66 M) vessel content: 18·9%

(c) Herbicide plant (value of equipment procured £0·81 M) vessel content: 40%.

46. An analysis of various plants purchased over three years was analysed to give the following indications of materials' usage. The percentages are based on value:

	Year	*Low carbon and low alloy* (%)	*Stainless steel* (%)
Pressure vessels	1964	75	25
	1965	27	73
	1966	34	66
Heat exchangers	1964	97	3
	1965	49	51
	1966	88	12
Tanks	1964	83	17
	1965	52	48
	1966	81	19
Site erected tanks	1964	100	—
	1965	—	100
	1966	—	—
Road and rail tanks	1964	98	2
	1965	100	—
	1966	—	—

47. With regard to pressure vessel requirements in pesticides, pressures are not very high and processes are not even entirely continuous. Stainless steel is used commonly and this sector is in many ways similar to light organic chemicals.

48. In respect of the sources of supply, using the example referred to in paragraph 46, the following breakdowns were obtained (percentages are based on the values given above):

Year	PVs		HEs		Tanks		Site erected tanks		Road – rail tanks	
	UK	Foreign	UK	Foreign	UK	Foreign	UK	Foreign	UK	Foreign
1964	51%	49%	100%	—	94%	6%	100%	—	62%	38%
1965	89	11	100	—	100	—	100	—	—	100
1966	100	—	100	—	100	—	—	—	—	—

Future pressure vessel demand in fertilizers and pesticides

49. As in nearly all growth sectors larger unit size plants can be expected with correspondingly larger vessels. Since nitric acid and, therefore, ammonia based fertilizers are growing at the expense of sulphuric acid based fertilizers, more high pressure vessels will be needed. The replacement of sulphuric acid by nitric is due to the increasing cost of mineral sulphur and the decrease in the number of active coke ovens. The general trend will be towards more stainless steel with a strong possibility of titanium becoming important. For high pressure ammonia plants high strength quenched and tempered steels can be expected to find an application.

50. In world-wide terms fertilizer consumption is growing rapidly at about 11% per year, although the growth rate in the United Kingdom is lower than this, at about 5% per year. The fertilizer market in the United Kingdom is dominated by two large chemical companies although two of the large petroleum groups are making determined assaults on the market. The potential represented by the UK market alone however, is probably not enough to sustain the massive investment in ammonia facilities which has been made by one leading chemical company in the period 1960–66, which may postpone further investment in fertilizer manufacturing facilities in the United Kingdom even for export, due to the very severe competition in world fertilizer markets. This competition is rendered all the more severe, for a number—and particularly the United States manufacturers—of significant international competitors benefit from the tied-aid programme of their governments, which is often linked to the purchase of fertilizers by the recipient country. One cannot, therefore, expect major investment programmes in fertilizer production in the United Kingdom over the next few years although a leading UK chemical company sanctioned a £3½ M plant in February 1968.

51. In pesticides, the present trend to using larger vessels will continue and will create an increasing demand for high tensile strength metals. Stainless steel will still be commonly used.

Inorganic chemicals

SIC (1958): MLH 271–3 parts

52. Inorganic chemicals include a very large number of chemicals, but the number of these calling for large tonnage plants is limited. Sodium hydroxide, sulphuric acid, sulphur dioxide and trioxide, hydrochloric acid, chlorine, titanium dioxide and sodium

carbonate are the main examples. Very heavy investments have been made in chlorine. Nitric acid, phosphoric acid and ammonia have been conveniently included under fertilizers.

53. Because this industry is much longer established, technical changes in it are not so apparent as in the petrochemical industry. Plant obsolescence is much slower, often reaching twenty years.

54. The chemicals produced in small quantities will still be processed by batch techniques although continuous processes are used for the tonnage chemicals mentioned above. The usual characteristics of continuous processes can be seen, viz. an increase in size, temperature and pressure where applicable. However, pressure does not play an important part in the above-mentioned chemicals except in the transport of chlorine and the production of anhydrous hydrogen chloride.

55. One company showed that the ratio of (pressure vessel and heat exchanger) orders with regard to (plant and equipment) expenditures varied considerably on a yearly basis, e.g. 10·8% in 1966 and 3·0% in 1967, with pressure vessels representing respectively 56·5% and 83·0% of each figure and heat exchangers the remainder. In a sulphuric acid plant, the vessel to total plant cost percentage was 16%, while the vessel to total equipment cost percentage was 28%; the UK fabricators providing 88% of the vessel needs. It should be noted that part of the reason for the high vessel percentage is that the plants do not require sophisticated control systems, etc.

56. Replacement demand is very small and usually concerns only such items as linings.

57. The main pressure vessels used are in mild steel. In one company mild steel represented 95% of pressure vessels used in terms of value. Other vessels were in monel, aluminium and copper alloys. Some vessels of mild steel for low temperature applications were also used. A certain number of vessels are lined with rubber or glass. Design pressures were usually well below 350 psig except for those vessels in the anhydrous HCl plant which were designed for 850 psig. Some high pressure vessels were large hydrogen cylinders for storage purposes.

58. The following distributions for the sources of supply have been obtained from the case history projects analysed:

Item	1966		1967	
	UK	Foreign	UK	Foreign
Pressure vessels	85%	15%	100%	0
Heat exchangers	73%	27%	50%	50%

59. Most vessels have been built to BS 1500 or 1515. One company has programmed the latter for computer work, and is also exploring the possibility of using standard sizes of pressure vessels for the simpler applications. Criteria for designating that vessels should be built to a pressure vessel design standard are the following:

(i) the *danger* of the process, which leads to Class I standards of construction to avoid leakages, even where the operating pressure is as low as 1·5 psig as in the case of HCN;

(ii) *the technical importance of the vessel* in the process which necessitates fabrication to highest standards;

(iii) the use of *minimum Class III standards* for all vessels excluding open tanks.

60. Although most fabricators claim to be able to build to most standards, this has not always proved to be true: even if the design is fairly straightforward, this does not mean that the fabrication is also straightforward, and special interpretation of the standard may be required. In fact, most purchases from abroad appear to have been made on technical grounds. Complete designs have occasionally been prepared by the final user, but these have usually been amended by the fabricator to suit his particular needs.

Future pressure vessel demand in inorganic chemicals

61. No important changes are expected in inorganic chemicals. Process control may be applied to this industry to a more appreciable extent, in which case the percentages of pressure vessel cost in new plant cost will fall.

Dyestuffs

SIC (1958): MLH 271·1

62. This sector is concerned with the manufacture of dyestuffs and dyestuff intermediates. The market depends mainly on outlets in the textile industry and export markets. The expected annual growth is approximately 8·4% per annum. Dyestuffs will probably continue to be made by batch techniques as the industry is essentially concerned with small quantities of high value chemicals. No technical changes are foreseeable in the near future.

63. A typical project gave the vessel cost to plant (excluding erection) cost percentage as 54%, of which 39% of pressure vessels were in mild steel and 61% in stainless steel.

64. One company interviewed indicated that pressure vessel replacement had represented approximately 21% of total maintenance over the past five years. Plant replacement is based on a 15 year basis depreciation.

65. The processes involved and the pressure vessels used are of a simple kind. One company interviewed indicated that three main types of vessels were used:

(i) Mild steel low pressure vessels (up to 50 psig working pressure). These varied from 8,000 to 30,000 litres capacity, most of them in the larger sizes;

(ii) Mild steel high pressure vessels of 750 psig working pressure;

(iii) Stainless steel low pressure vessels and pressure driers (up to 100 psig).

The most common vessel is the 30,000 litres mild steel vessel, which is normally 11 ft in diameter with a plate thickness of ¾"–1". Between one-quarter and one-third of the mild steel vessels are glass-lined.

66. Of the two companies interviewed, one relied mainly on foreign supply while the other only called upon continental fabricators when delivery times quoted by UK fabricators were too long for the plant construction programmes.

Future pressure vessel demand in dyestuffs

67. Plant sizes are growing larger and vessels will follow to some extent this trend. Some rationalisation of existing plant in the form of continuous processes can be expected. However, the impression formed in the interviews was that there was unlikely to be any significant changes in:

the ratio of vessels to plant investment;

the materials used;

the operating pressures and temperatures.

Industrial gases

SIC (1958): MLH 271-3 parts

68. The industrial gases include oxygen, nitrogen and carbon dioxide (which involve the highest tonnages) and argon, hydrogen and helium. Carbon dioxide is not growing at the same rate as the others but most comments about vessels needed for liquid oxygen apply to other cryogenic vessels.

69. Both the important industrial gas producers are also important contractors and have their own fabrication facilities, so this sector is not of considerable interest to jobbing fabricators. However, as these captive facilities have certain upper limits in capacity and range, the work put aside is not inappreciable. Most carbon dioxide vessels are made by regular fabricators.

70. The materials commonly used for cryogenic application are stainless steel (high strength will become important), aluminium and 9% nickel steel. The quality of all cryogenic vessels is very high and inspection is stringent. Vessels are not only subject to internal pressure but are normally surrounded by a jacket containing powder under vacuum. Thicknesses are medium (about ½") and most vessels are suitable for shop-building except for some very large storage vessels.

71. The vessels produced in the largest numbers (enough to merit almost series production) are:

storage and dispensing vessels, stainless steel inside with a mild steel jacket filled with powder under vacuum;

road tanker vessel, all aluminium, jacketed and vacuum powder filled.

Future pressure vessel demand in industrial gases

72. No very significant change in vessel types can be expected in the near future, although sizes may well go up, and 9% nickel steel may become of greater significance as problems associated with its production and welding are solved.

Secondary demand sectors

73. In all the following sectors the interviews indicated that only a modest demand for pressure vessels was generated due either to the small size of plants, the relative unimportance of pressure vessels in the plants or an absence of new investment in the sector. In nearly all long established sectors the need for new plant and new pressure vessels is limited due to slow growth rates.

Fine chemicals, pharmaceuticals and toilet preparations

SIC (1958): MLH 271–3 parts and 272

74. Most processes in this sector are batch and the vessels involved are small and for low pressure, eg 50 psig. Stainless steel as well as clad vessels are common. Some change to continuous processes can be expected but, except for stainless steel specialists, this sector will remain of secondary interest.

Coke ovens and coal tar products

SIC (1958): MLH 261 and 271–3 parts

75. As coal-based gas has progressively been replaced by gas manufactured from oil feedstocks, and both now are threatened by natural gas, no major investment can be expected either in new coke ovens or in plants based on coal tar. The amount of coal tar available for distillation is constantly declining. Chemicals based on coal tar are being continually replaced by petroleum-based products. The decrease in demand does not call for new plant investment of any magnitude. This sector is, therefore, of almost no interest for pressure vessel fabricators.

Synthetic resins and plastics

76. Although this sector is growing at an appreciable rate very few reactions of polymerisation require pressure (exception polyethylene) and corrosion problems are not severe. Thus the vessels for this industry, although numerous, are of low cash value.

Vegetable and animal oils and fats

SIC (1958): MLH 275 (1)

77. Batch processes are usual in this industry and because of purity specification fairly small stainless steel vessels are common. It may represent an area of future interest if a change to continuous processes takes place, as seems likely.

Sugar refining

SIC (1958): MLH 216

78. Pressures are low and vessels unsophisticated although stainless steel finds some application. This sector is also of little interest due to its slow growth rate.

Food and drink industries

SIC (1958): ORDER II, except 216 and 240

79. High pressures rarely enter into food and drink manufacturing processes, but low pressures, say 50 psig, are encountered. Brewery equipment is of interest as the processes are becoming continuous and sometimes lightly pressurised. Beer storage tanks are also under low pressure. The sector is of some interest to stainless steel specialists and for manufacturers of clad and lined vessels.

Pulp and paper

SIC (1958): MLH 481

80. Pressure vessels only find auxiliary applications in this sector and represent well under 1% of total investment.

Cement

SIC (1958): MLH 464

81. Pressure does not enter into the manufacture of cement. The use of pressurised transport systems for cement powder is of some interest. In these, pressures up to 100 psig are used. For a fabricator who wishes to set up a special production unit cement transporters may prove of interest.

Transport

82. This sector, although not requiring vessels for high pressure other than air receivers, is interesting in that series production of transport tanks is possible. Materials of construction are carbon steel, stainless steel and aluminium with various combinations for low temperature vessels (in particular for industrial gases). However, economic production of such vessels requires specialisation and they are, therefore, of limited interest to the jobbing fabricator. There is also the possibility of series production of air receivers or air reservoirs. These are usually simple vessels operating between 160–200 psig, but occasionally there are requirements for operation at much higher pressure, eg up to 3,000 psig.

ANNEX F

Pressure vessel price and delivery quotations

MINERAL OIL REFINING

Example of pressure vessel quotations for price and delivery are given below:

oil refinery (Spain)
(quotations at beginning of 1966)

	Price (£)	*Delivery* (*months*)
3 UK companies	12–14,000	12–15
1 Italian company	6,080	10

HEAVY ORGANIC CHEMICALS

Examples of price and delivery differentials have been drawn from a series of cases concerning different types of vessels.

(a) one quench boiler without bottom cover, 42″ diameter, $1\frac{7}{16}$″ shell thickness, 24 ft overall length, mild steel shell with chrome molybdenum tube plates (quotations in mid-1967):

		Price (£)	*Delivery* (*months*)
German companies	(1)	6,500	5
	(2)	11,700	6
	(3)	8,900	5–6
Italian companies	(1)	6,950	7–8
	(2)	10,300	7
	(3)	11,800	10
Dutch company		11,200	9–10
US company		13,830	8½
UK companies	(1)	13,300	9
	(2)	7,800	6½
	(3)	7,750	7½
	(4)	7,900	8
	(5)	9,250	10
	(6)	order unsuitable for economical fabrication	
	(7)	do not carry out this type of fabrication	
	(8)	no quotation received	

(b) Ethane quench boiler, comparable in all aspects to (a) (quotations up to the end of September 1967)

		Price (£)	*Delivery* (*months*)
German companies	(1)	6,096	7
	(2)	6,971	6

		Price (£)	*Delivery* (*months*)
UK companies	(1)	7,100	7
	(2)	6,850	7
	(3)	6,450	10
	(4)	7,250	6
	(5)	4,910	5½
	(6)	7,145	7

FERTILIZERS AND PESTICIDES

The following table analyses a sample of (lowest) delivery and price quotations for June, July and August 1967. Deliveries (D) are given in months and prices (P) in £.

Item	UK		Germany		Italy		Japan		France		Sweden	
	D	P	D	P	D	P	D	P	D	P	D	P
6 PV	8	57,070	7½	33,730	8	41,940	10½	49,760	8½	51,780	11	50,740
8 PV	9	122,910	11	99,340	7	60,320	10	102,340		—	11	82,360
10 HE	9	93,880		91,960	9	105,900	9	116,820		—		—

DYESTUFFS

One 1966 quotation, for a high pressure autoclave, produced the following results:

UK companies	(1)	£5,855	no delivery quoted
	(2)	£4,645	no delivery quoted
Italian companies	(1)	£2,300*	7 months delivery
	(2)	£3,237*	7 months delivery

*Excludes duty, but includes freight.

INDUSTRIAL GASES

Examples of price differentials are given below:

(a) Sweden UK (end of 1966)
£108,000 £111,000

This concerned 2 vessels, in different materials (stainless), assembled on site.

(b) Sweden UK (end of 1966)
£196,000 £357,000
£380,000
(stretched spheres) (cylinders)

(c) Sweden UK
£302,000 £525,000

These vessels were designed to different design standards. They were stretched and built in stainless steel. The Swedish process was technologically advanced which lowered vessel prices.

(d) Italy	UK	(March 1966)
£71,000	£100,000	

The order concerned two regenerators.

(e) Italy	UK	(March 1966)
£9,000	£10,000	

(f) Italy	UK	(March 1966)
£42,000	£77,000	

The order concerned a gaseous oxygen storage vessel.

SYNTHETIC RUBBER

The following examples of wide UK price and delivery differentials were given (these concern quotations for the same application):

(a) 1961–2: distillates receiver 4 ft length × 13 ft 3 in diameter, $\frac{3}{8}$″–$\frac{1}{2}$″ ends and $\frac{7}{16}$″–$\frac{3}{8}$″ shell thickness:

Prices of different UK companies	*Delivery time (weeks)*
£610	16
£579	16–20
£867	27–30
£773	28

(b) 1964: 5,000 gallon mild steel resin-lined vessels for transpolyisoprene plant, 12 ft length × 6 ft in diameter, $\frac{9}{16}$″–$\frac{5}{8}$″ shell thickness, 12 ft length × 9 ft diameter, $\frac{3}{4}$″–$\frac{5}{16}$″ shell thickness:

Prices of different UK companies	*Delivery time (weeks)*
£1,664	32
£1,749	27
£1,801	32
£1,668	27
£989	22
£1,007	22
£1,016	n.a.

(c) 1963: heat exchanger, 4 ft length × 5 in diameter:

Prices of different UK companies	*Delivery time (weeks)*
£74	3–4
£248	7
£120	14–16

(d) 1962: heat exchanger 10 ft length × 6 in diameter, 6 ft length × 8 in, 8 ft length × 10$\frac{3}{4}$ in diameter, 6 ft 9 in length × 5 in diameter, 8 ft length × 6 in diameter, 8 ft length × 8$\frac{3}{8}$ in diameter:

Prices of different UK companies	*Delivery time (weeks)*
£437	24–28
£679	24–28
£555	n.a.
£540	n.a.
£289	10–12
£240	12–14
£295	18–22

(e) 1962: heat exchanger, 8 ft length × 10 in diameter, 12 ft length × 5 in diameter, 16 ft length × $6\frac{5}{8}$ in diameter, 6 ft length × 8 in diameter, 8 ft length × $10\frac{3}{4}$ in diameter, 6 ft 9 in length × 6 in diameter:

Prices of different UK companies	*Delivery time (weeks)*
£245	12–14
£449	24–28
£530	24–28
£679	24–28
£555	24
£540	n.a.
£352	10–12

FINE CHEMICALS, PHARMACEUTICALS AND TOILET PREPARATIONS

(a) Stainless steel reactor—2,000 gal capacity, detachable covers, $\frac{5}{16}$ in shell, built to the company's specifications, March 1967:

		Prices (£)	*Delivery time*
UK companies	(1) quote	8,380	40–44 weeks
	(1) requote	7,380	32–36 weeks
	(2)	5,118	26–28 weeks
	(3)	7,032	32 weeks
	(4)	6,465	26 weeks
	(5)	4,650	28–30 weeks
	(6)	4,325	24–26 weeks
	(7)	7,511	36 weeks
Swiss companies	(1)	4,650	24–26 weeks
	(2)	4,000	28 weeks

(b) Stainless steel reactor—1,250 gal capacity, fixed covers, $\frac{5}{16}$" shell, August 1965:

		Prices (£)	*Delivery time*
UK companies	(1)	6,400	52 weeks
	(2)	5,780	28–36 weeks
	(3)	3,425	30 weeks
	(4)	4,020	40 weeks

Analysis of delivery situation during 1965–1966 *by a major UK contractor*

Delivery situation during 1965–6 in respect of two major export contracts, with equipment supplied ex-UK, is given in the following table:

Months late in delivery		0	1	2	3	4	5	6	7	
Item	Total number of items	Number of items late by the indicated number of months								
Columns	9	—	—	2	3	—	1	3	—	
Heat exchangers	26	2	4	5	—	5	2	4	4	
Tanks	8	—	3	4	1	—	—	—	—	
Vessels	32	2	6	6	5	6	3	4	—	
Total number items	75	4	13	17	9	11	6	11	4	
Total 'item-months' late		0	13	34	27	44	30	66	28	=242

Average 'lateness' of all items $=\frac{242}{75}=3\cdot 2$ *months.*

ANNEX G

Leading chemical engineering contracting companies in the world

The only organisations which are excluded from the list are the State Contracting Organisations of some of the COMECON COUNTRIES which have already been given in Chapter 15. The address given is that of the parent company, and a number of the American companies listed have subsidiaries in the United Kingdom.

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
AUSTRIA	Voest AG Linz/Donau	F—PV	No indication
BELGIUM	Coppee-Rust S.A. 251 av. Louise Brussels 5	F	France, UK, Germany, Spain, USA
	Mechim SA 31 rue du Marias Brussels	—	No overseas companies
	Sybetra SA 66 Bd de l'Impératrice Brussels 1	No indication	—
	Soc. Entreprises et Construction à l'Etranger 186 av. Louise Brussels 5	—	—
FRANCE	Air Liquide 75 Quai d'Orsay Paris 7e	F—PV	USA, Canada, Italy, Spain, Japan
	Technip 232 av. Napoléon Bonaparte Rueil-Malmaison (Seine et Oise)	—	—
	ENSA 5 Rue de Montessuy Paris 7e	F—PV	—
	SFTS 52 Champs Elysées Paris 8e	—	—

Abbreviations used: F =fabricating facilities
PV=pressure vessels
— =none

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
FRANCE —cont.	Gexa SA 6 bis rue des Graviers 92 Neuilly-sur-Seine	F—PV	—
	Ets. A. Herlicq et Fils 35 rue Bassano Paris 8e	F—PV	—
	SA Heurtey 30–32 rue Guersant Paris 17e	—	Belgium, Germany, Italy, Spain, Sweden, UK, USA, South Africa
	Kaltenbach et Cie 3 av. Erlanger Paris 16e	F	—
	Krebs & Cie 59–61 rue Poucher Paris 17e	—	Belgium, India, Canada
	Sté. Onia Gegi 4 Pl. des États-Unis 92–Montrouge	F—PV	Only overseas agencies
	Speichim 106 rue d'Amsterdam Paris 9e	F—PV	Italy, agents in 67 countries
	SPIE 75 Bld. Haussmann Paris 8e	—	—
	STEC 192 Grande Rue 92–Sèvres	—	—
FEDERAL REPUBLIC OF GERMANY	Didierwerke AG Alfredstrasse 28 43 Essen	F—PV	—
	Klöckner-Humboldt-Deutz Methweg 6 5 Köln-Nippes	F—PV	—
	Heinrich Koppers GmbH Moltkestrasse 29 43 Essen 1	F	France, Spain, India, Japan
	Friedrich Krupp Essen	F—PV	No indication
	Linde AG 8021 Höllriegelkreuth Munich	—	France, USA
	Lurgi Gesellschaften Gerninusstrasse 17/19 6 Frankfurt-am-Main	—	France, Italy, UK, Switzerland, Sweden, Spain, Canada, USA, Australia, India, Japan, South Africa

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
FEDERAL REPUBLIC OF GERMANY —cont.	Dr. C. Otto & Co. GmbH Christstrasse 9 Bochum	F—PV	France, Italy, Holland, Spain, USA, India, Japan, Argentina
	Pintsch Bamag AG Wetzlarer Strasse Butzbach, Hessen	F—PV	Representatives in 70 countries
	Carl Still Recklinghausen	—	—
	Friedrich Uhde GmbH Deggingstrasse 10/12 46 Dortmund	F	UK, USA, offices: Japan, USA, worldwide representation
	Zahn & Co. GmbH Julius Wolff Strasse 2 325 Hameln-Weser	—	—
	Chemibau Dr. Zieren 5 Köln-Braunsfeld	No indication	Only overseas agencies
	Vickers-Zimmer AG 6 Frankfurt-am-Main	F—PV	UK, Netherlands
HOLLAND	Comprimo NV Europahuis 99 James Wattstraat Amsterdam–0	—	—
	Continental Eng. Lutmastraat 2 Amsterdam	F—PV	Mexico, Iran
ITALY	CTIP Piazzale G. Douhet 31 Rome (EUR)	—	Belgium, France, USA, Brazil
	Oronzio de Nora via Bistolfo 35 Milan	F—PV	Associated companies and representatives in W. Europe, Latin America, USA, UAR, India
	SNAM Progetti SpA San Donato Milanese Milan	F	France, Spain, Australia, USA offices: world-wide
	Italimpianti Piazza Piccapietra 9 Genoa	F	No indication
	Techint via Cerva 46 Milan	F	Offices: W. Europe, USA, Latin America, Middle East
	Technider via S. Sofia 27 Milan	—	—

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
SWEDEN	Gothenburg Plant Construction Gothenburg	F	—
UNITED KINGDOM	CJB Ltd. CJB House Eastbourne Terrace London, W2	—	Canada, Australia
	Matthew Hall P.O. Box 404 Matthew Hall House 101–8 Tottenham Court Road London, W1	F	Spain
	Humphreys & Glasgow 22, Carlisle Place London, SW1	—	Australia, Canada, India, representatives: W. Europe, South Africa, Iran, Japan, Latin America
	The Power-Gas Corp. Ltd. P.O. Box 21 Bowesfield Lane Stockton-on-Tees	F	South Africa, Australia, India, France, United States
	Petrocarbon Developments Ltd. Petrocarbon House Sharston Road Wythenshawe, Manchester	—	No overseas offices
	Simon-Carves Eng. Ltd. Cheadle Heath Stockport/Cheshire	—	Spain, Canada, Australia, South Africa, India, Japan
	Tarmac Civil Engineering Ettingshall Wolverhampton	F	South Africa
	Vickers-Zimmer Ltd. Vickers House Millbank/London, SW1	—	UK, Canada, Japan
	Whessoe Ltd. Darlington/Co. Durham	F—PV	Factories: France, Nigeria; Agents in 16 countries
	George Wimpey M.E. Flyover House Great West Road Brentford/Middx	—	Australia, Bahrain, Canada, Ethiopia, Nigeria, South Africa, Spain, Trinidad
	Woodall-Duckham Construction Co. Ltd. Woodall-Duckham House The Boulevard Crawley/Sussex	—	—

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
JAPAN	Chiyoda Chem. & Eng. Chiyoda Building No. 3–3, 3–chome Akasaka, Minato-Ku/Tokyo	F—PV	Agents in Western Europe and USA
	Hitachi Ltd. New Marunouchi Bldg. Chiyoda-ku/Tokyo	—	No indication
	Hitachi Zosen 47 Edobori, 1–chome Nishi-ku/Osaka	F—PV	Offices in UK, USA, Federal Republic of Germany, Norway, Hong-Kong
	Ishii Iron Works Sukiya-Bashi Bldg. 3 Ginza Nishi, 4-chome Chuo-ku/Tokyo	F—PV for storage tanks	No indication
	Ishikawajima-Harima Ohte-Machi, 2-chome Chiyoda-ku/Tokyo	F—PV	Offices in W. Europe, North and South America, South Africa
	Japan Gasoline Co. New Ohtemachi Bldg. Chiyoda-ku/Tokyo	F	No overseas offices
	Kobe Steel Works 36, 1–chome Wakinohama-cho Kukiai-ku/Kobe	F—PV	USA and Federal Republic of Germany
	Mitsubishi Ltd. 6 Marunouchi, 2–chome Chiyoda-ku/Tokyo	F—PV	No overseas offices
	Mitsui Zosen 6–4 Tsukiji, 5–chome Chuo-ku/Tokyo	F—PV	Representatives in USA, UK and Federal Republic of Germany
	Mitsubishi Heavy Ind. 10 Marunouchi, 2–chome Chiyoda-ku/Tokyo	F—PV	Offices and representatives in USA, UK, Federal Republic of Germany, Norway, India, Thailand, Hong-Kong and Australia
	Niigata Eng. Co. 27–7 Taito, 2–chome Taito-ku/Tokyo	F	Offices in Brazil and Argentina
	Toyo Eng. Co. 3–5 Nihonbashi Honshu Chuo-ku/Tokyo	F	Office in India
	Yawata Chemical Eng. Ginza-higashi Chuo-ku/Tokyo	F—PV	No indication

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
SOUTH AFRICA	Vecor Projects Ltd.	—	No overseas offices
USA	Air Products Inc. P.O. Box 538 Allentown, Penn.	F—PV	UK (factory PV), offices in Federal Republic of Germany, Italy, Belgium
	Allis Chalmers Inc. Milwaukee 1 Wisconsin	F	Offices and representatives throughout the non-Comecon world
	Badger Co. Inc. 363 Third Street Cambridge, Mass.	—	Main overseas offices in UK and Holland. Offices in Canada, W. Europe, South Africa
	Bechtel Corp. 220 Bush Street San Francisco/Calif.	—	Offices throughout the non-communist world
	Blaw-Knox Co. 300 Sixth Avenue Pittsburgh/Pa.	F	France (Factory) and Japan (the equipment manufacturing division) offices and agencies throughout the world
	C. F. Braun & Co. Alhambra/Calif.	F	Offices in Canada and UK
	Brown & Root Inc. P.O. Box 3 Houston 1/Texas	—	Offices in Canada, Latin America and W. Europe
	Catalytic Construction 1528 Walnut Street Philadelphia/Pa.	—	Canada and UK
	Chemico 320 Park Avenue New York/N.Y. 10022		UK, France, South Africa
	C. & I. Girdler Inc.	F	Belgium, Federal Republic of Germany, UK
	Crawford & Russel Inc. 733 Canal Street Stamford/Conn. 06904	—	Office in Holland
	Dorr-Oliver Inc. 77 Havemeyer Lane Stamford/Conn. 06904	F	Offices and subsidiaries throughout the non-communist world

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
USA —cont.	Fluor Corp. 2500 South Atlantic Bld. Los Angeles/Calif.	—	Offices and subsidiaries in UK (principal), Sweden, Holland, Canada, South Africa, Panama
	Foster Wheeler Corp. Livingstone/New Jersey	F	Offices and subsidiaries in North and South America, W. Europe and Japan
	Jacobs Eng. Co. 837 South Fair Oaks Ave. Pasadena/Calif.		No overseas offices
	M. W. Kellogg Co. 711 Third Avenue New York/NY 10017	F	UK (most important), France, Federal Republic of Germany, Spain, Australia, Argentina, Brazil, Colombia, Venezuela
	Koppers Co. Inc. Koppers Building Pittsburgh 19/Pa.	—	Office in Switzerland
	Litwin Corp. 520 East William Street Wichita/Kansas	—	France and Israel
	Lummus Co. 385 Madison Avenue New York/NY 10017	F	UK, France, Holland, Spain, Italy, Canada, Iran, India, Japan, Venezuela
	A. G. McKee & Co. 2300 Chester Avenue Cleveland/Ohio	F	Canada, Australia, Chile, Mexico, Brazil, Argentina, France, Spain
	The Ralph M. Parsons Co. 617 West Seventh Street Los Angeles 17/Calif.		W. Europe, Middle East, Japan
	J. F. Pritchard & Co. 4625 Roanoke Parkway Kansas City/Missouri		Subsidiaries in Canada, offices throughout the free world
	Procon Incorp. 111 Mt. Prospect Road Des Plaines/Ill.	—	North and South America, W. Europe, Australia, Far East

Country	*Name*	*Fabricating facilities*	*Overseas offices and subsidiary companies*
USA —cont.	Scientific Design 2 Park Avenue New York/NY 10016	—	Offices and subsidiaries in Canada, UK, France, Switzerland, representatives in Japan, Mexico and India
	Selas Corp. of America Dresher/Pa. 19025	F	Netherlands, Switzerland
	Stearns-Roger Corp. 660 Bannock Street Denver/Colorado	F	Canada and Mexico
	Stone & Webster 225 Franklin Street Boston Mass. 02107	—	UK, France, Belgium, Holland, Canada, Australia
	Struthers Scientific & International Corp. International Building 630 Fifth Avenue New York/NY	F	France and Mexico
	Vulcan Cincinnati Inc. 120 Sycamore Street Cincinnati/Ohio	—	No overseas offices
	Weatherby Eng. Co. P.O. Box 36292 Houston/Texas	—	No overseas offices
	D. M. Weatherly Co. 1800 Peachtree Road Atlanta/Georgia	F	No overseas offices
	Wellmann-Lord Inc. New Mulberry Highway Lakeland/Florida	—	No overseas offices

ANNEX H

Leading pressure vessel fabricating companies abroad

Companies in France

CONSTRUCTIONS METALLIQUES DE PROVENCE

1. CMP incorporates CMO itself and Constructions Métalliques des Ardennes. Issued capital is FF 15 M. The company has three fabrication units, all specialised in pressure vessel construction: at Arles, close to the Mediterranean, at Sedan in the Ardennes, and at Dunkirk, the more recent and with the heaviest equipment.

2. CMP is highly specialised: the complete range of its product field is the following:

tanks;

pressure storage tanks;

refrigerated storage under low and very low temperature;

all sorts of pressure vessels, especially reactors, towers, columns, heat exchangers, spherical reactors, etc.

3. CMP has been ranked by some contractors as the leading company in Europe as a builder of spherical pressure tanks for gas storage.

4. Specialised in the fabrication of pressure vessels for the refinery and petrochemical industry, CMP has built a wide range of pressure vessels to a number of foreign standards, especially to the API 650, and all the relevant ASME standards. CMP's prices are said to be usually higher than those of any other European pressure vessel fabricator, the emphasis being laid on reliability in quality and delivery and other services. Amongst CMP's recent deliveries were a clad steel distillation tower of 81 tons with a diameter of 5′ 6″, and an overall length of 172′, and an atmospheric tower of 118 tons, 18′ diameter and 150′ in height.

5. Plate forming capacity is up to 5″. Automatic welding is used wherever possible. Welds are usually inspected by Cobalt-bomb gamma rays. CMP build pressure vessels in various materials.

SCHNEIDER-CREUSOT

6. Schneider- Creusot is one of the largest industrial groups in France, with a powerful financial background. The company is interested in iron and steel as well as in a variety of steel fabrications. In the pressure vessel field Schneider-Creusot fabricates a wide range of products from boilers to high-pressure process and storage materials. It is the only company (perhaps with CMP) fabricating very high pressure vessels. Further important specialisation is in heavy forgings.

7. The upper working plate thickness in Schneider-Creusot's shops is in the order of 8" to 10", with a cranage capacity in the neighbourhood of 300 tons. The company is at present able to build vessels up to 500 tons and plans an extension to cover 800 tons.

8. Engineering contracting for industrial plant installations is carried out for Schneider-Creusot by the group's engineering subsidiary, ENSA, one of France's leading chemical contractors.

SOCIETE FRANCO-BELGE SA

(Issued capital: FF 13 M)

9. Employees: about 1,300 (of which 100 are engineers and 200 are technicians and draughtsmen mainly operating in a separate research bureau).

10. Fabrication: steel products, railway rolling stock, general mechanics, steel framework, forging, heavy boilerwork, etc. Engineering and fabrication of complete chemical plants.

11. Main pressure vessel production: spherical and other pressure storage tanks, reactors, stabilisation-distillation-absorption, etc. towers, Foster-Wheeler boilers, heat exchangers, etc., up to 150 ton unit-weight.

12. Main equipment: plate forming up to 55 mm, 4 automatic Union Melt welders, 30 semi-automatic electrical welding apparatuses, 20 Argon and 40 other electrical welders, gamma, X-ray and ultrasonic inspection devices, etc.

13. Franco-Belge has a working association with Herlicq et Fils (engineering contractors) and Herlicq has a majority interest in Franco-Belge. Herlicq specialises in the refinery, hydrocarbon processing and iron making industries, and often works in association with an American chemical contracting group.

VALLOUREC

14. This company is a specialist for all types of dished ends and supplies the bulk of the French industry's requirements in all steels and alloys, including a range of clad steel dished ends. Vallourec also build pressure vessels, but mainly for storage under pressure. The quality of Vallourec's dished ends seems to be highly appreciated by their French customers.

CAFL – COMPAGNIE DES ATELIERS ET FORGES DE LA LOIRE

15. With a capital of FF 123M, CAFL fabricates iron and steel products, railway rolling stock, machines and motors, etc. They are France's second dished ends supplier and, in the pressure vessel field they specialise in large forgings.

BRISSONNEAU ET LOTZ

16. An important fabricator of industrial machines and equipment, electric and other motors, diesel, diesel-electric and electric locomotives, B & L specialise in heat exchangers of the higher pressure range in all metals, especially high quality steels and alloys.

LORRAINE-ESCAUT

17. This company is engaged in the production of iron and steel, and steel products, and of all forgings and heavy mechanical construction. Lorraine-Escaut is a leading iron and steel producing company in Western Europe. The specialisation in pressure vessels is not important at group level.

CHANTIERS DE L'ATLANTIQUE

18. Chantiers de l'Atlantique is France's leading shipbuilder. In the pressure vessel field they specialise in medium and heavy fabrication, especially thin wall high-pressure vessels (licence Multiwall from Struther Wells, USA) and marine and other boilers. The excellent production control of this fabricator was mentioned by one leading British chemical contractor—every pressure vessel is programmed through the factory computer, based on a standard time basis.

19. Chantiers de l'Atlantique, SOCALTRA (Societe Alsacienne d'Etudes et de Travaux: pipe, boilerwork and heat exchangers), ALSTHOM (boilers and electric machinery for process industries) and Fives-Lille-Cail (machinery, pumps, boilers, etc.) work in association with GEXA, an important engineering contractor. It does not seem, however, that they actually have a significant share in the country's pressure vessel market.

20. Another and more recent working integration appears more important, and involves Société Française de Construction Babcock et Wilcox; Chantiers de l'Atlantique and Société Fives-Lille-Cail. S.F. de C. Babcock et Wilcox and Chantiers de l'Atlantique founded (in 1967) the Babcock Atlantique on the basis of all the production facilities of the two founders in the fields of the production of boilers, heavy boilerwork and nuclear engineering, and the industrial refrigeration facilities of Chantiers de l'Atlantique. Fives-Lille-Cail is associated with the new Babcock-Atlantique's activities for the production of boilers and nuclear heat exchangers. Babcock-Atlantique will have an approximate turnover of 500 million francs (about £36M) per year. The S.F. de C. Babcock et Wilcox specialises in heavy boilers (for thermal power generation, etc.) and equipment for oil refineries, nuclear plants, etc., and Societe Stein et Roubaix in boilers (mainly heavy) and heat exchangers. It is estimated that Babcock et Wilcox, Stein et Roubaix, and Fives-Lille-Cail supply practically all the heavy boilers installed by EDF (Electricité de France), their respective share of the market being 50%, 30–35% and about 15%.

21. A selection of medium-size French companies producing pressure vessels is given in Table H(1).

TABLE H(1)

Selected medium-size French companies producing pressure vessels

Name of company	Capital or No. of employees or area of shops	Main manufacturing interest	Specialisation in pressure vessels	Maximum working performance and/or equipment
Alpes-Rhone	Heavy fabr. shops of 10,300 m²	Heavy boiler and steel framework	Towers, columns, spherical pressure tanks	50 mm wall thickness 110 tons in weight: automatic welding and oxy cutting, etc.
Arbel SA	Cap. F 13 M	—	Series production of small dished ends	—
Blaw-Knox France	—	Ind. plants: fabrication and eng.	Separators	—
Ateliers et Chantiers de Nantes	Cap. F 16 M	Constr. in metals	Heat exchangers and pressure tanks	—
Ateliers de Construction de la Seine Maritime	—	Shipbuilding, storage tanks, etc.	Pressure storage tanks, boilers	—
Delattre-Levivier	1,800 employees	Heavy boilerwork tanks	Pressure storage	—
Ets. Richard Ducros	Cap. F 3 M	Pipe-steel framework and heavy boilerwork	Boilers and pressure tanks	50 mm wall thickness 90 tons, 50-ton sections
Exploitation d'Usines Métallurgiques	Cap. F 7.4 M	Heavy boilerwork	Pressure vessels and boilers	—
Groignard SA	Cap. F 5.2 M 900 employees	Machine tools, forgings, boilerwork	High-pressure tanks, towers, columns, etc.	40 mm wall thickness One-piece forgings up to 5 tons
Cie Fr. d'Entreprises Métalliques	Cap. F 50 M	Steels frames, heavy boiler-work, etc.	Pressure tanks and HE all steel alloys	Maximum wall thickness 80 mm
Münch Frères	1,200 employees	Boiler and framework	Smaller-size high-pressure vessels	Max. plate thickness: 35 mm
Pacquet, Tesson & Cie	—	Welded steel frame and boilerwork, etc.	PV in all high alloys reactors for nuclear plants, etc.	Max. plate thickness: 120 mm
S.A.C.M. – Alsacienne de Constr. Mecaniques	Cap. F 56 M	All mechanical construction	Boilers and HE	—

Note: Only those companies upon which documentation could readily be obtained are listed

Companies in the Federal Republic of Germany

22. A detailed investigation was not carried out in Germany. However, certain categories of companies are presented on the basis of some companies typical of each of the categories:

large integrated pressure vessel fabricators,
medium-size companies fabricating pressure vessels,
smaller medium-size companies,
non-regular fabricators.

23. *Large integrated fabricators.* The companies in Table H(2) appear to lead the pressure vessel industry in the Federal Republic of Germany. The fundamental characteristics of their *industrial* integration is vertical in that it goes from a captive raw materials basis to finished (mainly industrial) products. There are two special cases of large companies as follows:

> The DEUTSCHE BABCOCK AND WILCOX AG can be assigned to none of the categories. With its 6,000 workers, the company realised an overall turnover of £26M in 1964. Atomic reactors, heat exchangers, boilers, and various pressure tanks were among the main products of the company. It was, however, not possible to determine the share of pressure vessel production in the overall turnover.
>
> The largest company with important specialisation in pressure vessels is BORSIG AG in Berlin. Apart from the large integrated companies Borsig is the only pressure vessel fabricator often mentioned by contractors when discussing the German market for pressure vessels. With its 5,000 workers, Borsig realised an overall turnover of about £25M in 1965. The principal specialisation in the pressure vessel field concerns heat exchangers for nuclear reactors (power generation). All kinds of pressure vessels are constructed, especially high-pressure, in special high strength steels and alloys. The company fabricates a wide range of installations for the chemical, gas refinery, and iron and steel industries.

24. *Medium-size fabricators* are indicated in Table H(3).

25. *Smaller medium-size companies:* examples are given in Table H(4). The companies listed are all independent, selling on the open market. HAGEMANN, HERING AND SCHMIDT seem to be mainly family interest. The number of workers by company is between 130 and 260, and their turnover between £0·5M and £1·6M. Although they are competing for pressure vessel orders all over the Federal Republic of Germany, some of them also in other West European countries, companies of this category cannot have a significant influence on market conditions. This class is mainly important for the construction of boilers, with the major exception of Schmidsche GmbH, specialising in the production of high pressure heat exchangers for process gases. As for the market orientation of both of the above categories of companies it was not possible to determine the extent to which their products are marketed through German based contractors.

TABLE H(2)

Large integrated pressure vessel fabricators in the Federal Republic of Germany

Name of company	Integration	Group product range	Specialisation in PV	Main market interest for PV	*Notes*
Pintsch Bamag	Linked to Thyssen-Bornemissza: operates as contractor	Iron and steel, machines and equipment, PV, etc.	corrosionless	PV with P–B processes: gas, etc., Europe incl. UK and Latin America	Considered by contractors as good, but not for specialisation
Essener Apparatebau	Partnership with Mannesmann		high-alloy PV	Paper-pulp, petrochemical Europe	—
Fr. Krupp Apparatebau	Krupp	Krupp	multilayer PV	PV for food, chem. and petrochem. ind.	Turnover of the company: about £3 million
Rheinstahl-Henschel-Werke	German steel and American interests	steel products, rolling stock, machines, etc.	dished end and all kinds of PV	chemical and other ind.	Henschel total turnover: about £45 million
M.A.N.	15 to 100% subsidiaries: linked to Oberhausen	steel, vehicles, motors, incl. equipment, etc.	HE, B, T, etc. all specialities	nuclear reactors steel-chem. and petrochem, etc. ind.	total turnover: £120 million Export turnover: £36 million
Klöckner-Humboldt Deutz	K–H–D	steel structures, vehicles, motors, trucks, rolling stock, etc.	high-alloys, clad, etc.	metallurgical and chem. ind. Europe and world	total turnover: about £136 million
Gutehoffnungshütte Oberhausen, Sterkrade AG	belongs to Gutehoffnungshütte-Aktienverein	complete iron and steel structures, ships up to 3,000 t., nucl. techn. ind. apparatuses, etc.	heaviest and highest pressures, all steel qualities forgings, dished ends	refinery, chem. and petrochem. ind., Europe and World	Sterkrade's total turnover: £35 million
Mannesmann; M's wholly owned subs., specialising in PV is Mannesmann–Stahlblechbau GmbH., Düsseldorf	several wholly owned subsidiaries in the metal working ind. + many 25 to 75% participations, mainly metal–mech. + export activities	coal ores mining, iron and steel, steel processing, all mech. ind., incl. shipb.	all H–PV and HE, B, T, etc. dished ends, supplies steel to PV fabricators	all industries, especially liquid gases and refinery PV for transportation; exp. Europe and World	M. Stahlblechbau turnover in PV estm. at £73 million in 1964. Very high reputation for steel and PV
Stahl- und Rohrwerk Reisholz	links with Thyssen Bornemisza. Sells equip. with own processes	steel and iron products forging, pipes, rolling stock reactors, etc.	very high temp. and pressure, esp. for nucl. reactors	equipment for all ind. Europe and World	Considered one of Germany's best PV fabricators

Source: Compilation based on interviews, company brochures and trade journals

TABLE H(3)

Medium-size companies engaged in pressure vessel construction

(No. of workers: 250 to 2,000)

Name of company	General activity	Specialisation in PV	Market activity	Estimated turnover in PV £'000's
E. Ahlhorn AG	General mechanical	HE and T	—	—
Balcke AG	Ind. equipment	HE	W. Europe	410
Bergdorfer Eisenwerke AG	Ind. equipment	HE and T	W. Europe	270
Eisenhütte Prinz Rudolf AG	Equipment for chem. ind.	—	—	—
A. Ellinghaus	Ind. equipment and machinery	PV and T	—	—
Schmidtsche Heissdampf GmbH	Ind. equipment (proc. gases)	H-PV, HE and B	mainly W. Europe	450
Siegner AG	Steel construction	B and HE	mainly W. Europe	—
J. Stahl	Ind. equipment	B, T, and PV	—	230
Standardkessel Duisburg	Steam boiler construction	B	—	—

Note: H–PV = high-pressure vessels
PV = pressure vessels
HE = heat exchangers
B = boilers
T = tanks

TABLE H(4)

Smaller medium-size pressure vessel fabricators

Name of company	Activity		Market activity	Estimated turnover in vessels (£'000)
	General	Specialisation in vessels		
M. H. Kock GmbH	Gen. mechanical	HE	West Europe, was at Earls Court, London, in 1965	130
OAB Bodenpresserei GmbH	—	Dished ends up to 4·0m. diam.	—	—
C. Aug. Schmidt	Vacuum equipment	HE for ref.	West Europe, Earls Court, London, in 1965	—
Gebr. Hagemann AG	Steel const. and containers	PV and T	—	—
Oschatz GmbH	Specialises	B	—	260
Poehagen & Pfahler GmbH	Gen. mech.	B, PV and T	—	180
A. Hering AG	Equipment for chem. ind.	HE and B	—	140
Ratinger AG	—	HE, T and Forgings	—	—

Note: PV=pressure vessels; HE=heat exchangers; B=boilers; T=tanks

26. *Regular and non-regular fabricators.* Although the market effect of non-regular fabricators is of some importance, they are given much less attention in Germany than in the UK or in France. This may be partly due to the contractors' attitude: they claim to give orders for pressure vessels only to fabricators they know for the quality of their products: price is claimed to be a secondary factor. It is practically impossible to distinguish between regular and non-regular or time-to-time fabricators. Indeed, it is thought that once a non-specialised heavy fabricator started building pressure vessels and was technically and economically successful, he could no more be considered as a time-to-time pressure vessel builder, and he would try to remain permanently active in constructing pressure vessels. A distinction can be made, however, between the extent to which various companies are specialised in the pressure vessel field.

German pressure vessel shop layout – one example (not necessarily typical)

27. The present workshop layout of one large German pressure vessel builder did not follow any comprehensive plan for material and vessel movement. The workshop's site was 116 years old and as a result considerable time and costs were involved in movement between the various shops. A plate could travel a total of 3,000 metres between stockyard and final despatch from the works. Despite the handicap of piecemeal expansion there was plenty of room in the workshops. The company was now building a new works on the River Rhine which should help to reduce the cost of making a pressure vessel by 20%. The main fabrication shop would be 300 metres long and would be served by road, rail and river. Materials would travel only 120 metres compared with

the 3,000 metres of the old works. New equipment to be installed included gamma ray inspection. A considerable part of the cost of the new works was to be obtained by selling the old site for re-development.

Companies in Italy

28. Table H(5) gives a comparison of the major companies, as drawn from the interview programme in Italy. Further details are given following the table.

TABLE H(5)

Major Italian fabricators

Company	Specialisation (i.e. current work)	Approx. No. of emplys.	Usual No. of shifts	Capacity(1)		Estimated turnover £M/yr.(4)
				Total tons/ month	Heat exchangers t/month	
FBM	Heat exchangers (mainly) and columns	500(2)	2 in plate forming dept.; 1 in mech. dept.	5–600	50–60	4
Bonaldi	As above	500	1; 2 in some depts.	500	—	3·5
Belleli	As above	Approx. 300(3)	1	3–400	about 30	2
Sartori	70–80% columns and pressure vessels	2–300	2–3	500	20–30	2
Nuovo Pignone	Columns and vessels	800 at Massa	2–3	1,000	—	4·5
Bosco	—	600	3	800	70	4

(1) Two different terms of measure that are not comparable

(2) Plus 2–300 at subsidiary Hudson Italiana, Mantova

(3) In Mantova, total possible 1,000–1,500 since they also carry out erection and have works in Catania and Brindisi.

(4) Turnover figures, as they are not published they have been estimated on the basis of various factors, and are to be taken as a guide only.

BONALDI SPA CREMA

29. Bonaldi is one of the oldest and better known Italian pressure vessel fabricators, having started the manufacture of boilers and vessels at Crema in 1907. It specialises today in medium and large size installations for petroleum and petrochemical plants.

30. Typical of the larger Italian pressure vessel manufacturers, Bonaldi is known to have fairly advanced equipment. It is believed that it does not differ greatly from that which can be found installed in a comparable British fabricator. The following is taken from Bonaldi's statement of capabilities:

cold rolling of steel sheets, up to 3" and hot rolling up to 7";

fabricating dished ends, with diameter up to 8′ 2";

automatic and manual welding of pressure vessels to the maximum diameters allowed for truck and rail transportation;

inert gas welding;

turning on horizontal lathes of workpieces up to 4′ $\frac{11}{16}$″ diameter and 20′ length;

turning on face lathes of workpieces up to 10′ diameter;

turning on vertical turning and boring mills of workpieces having a diameter up to 6′ 6¾″;

drilling of tube sheets, up to a diameter of 10′;

milling and planning of metal parts for chemical processes;

precision bold threading with automatic machines;

annealing up to 2,200°F of pressure vessels up to 10′ diameter, 52′ 6″ length and 75 tons weight;

radiographic, gammagraphic, magnaflux equipment and ultrasonic inspection to check welds or materials;

all recognised and approved testing methods for materials.

FBM SPA MILAN

31. FBM is one of the more prominent companies in the Italian pressure vessel industry, and started pressure vessel fabrication post-war. The company is particularly known for its production of pressure vessels in stainless and alloy steels, clad steels and non-ferrous including reactive metals. The company is frequently praised by chemical engineering contractors for its heat exchangers, due to very modern plant and excellent shop layout. The company was reportedly the first in Europe to buy the giant Lahr driller. This is a very advanced single spindle computer programmed machine.

32. FBM's present works are in Milan with an area of about 30,000 m^2, of which about 12,000 m^2 are covered. The firm is about to move into the country about 35 km north-east of Milan on an area of about 600,000 m^2.

33. The present works are divided into several shops including machines of the same type: a complete mechanical shop, welding preparation and fabrication facilities, rolling, bending and cutting machines, stress relieving furnaces, prefabrication assembling and auxiliary equipment. The works are provided with an efficient internal transport and hoisting system, internal rail siding and excellent road connections.

34. The production plants are integrated by laboratories for mechanical tests, control of material and non-destructive tests as well as by a department for welding research and equipment for controlling the finished products.

35. The following particulars can be mentioned:

total installed capacity of electric power sub-stations (2,000 KVA);

welding: submerged arc automatic units, shielded arcwelding units, special titanium and similar metal structures, and welding facilities;

sheet cutting: heavy duty cutting and bevelling machines, 12,000 mm effective width, and other minor cutting units;

boring and drilling: No. 2 fully automatic electronically controlled boring machines; drilling and boring units of any size;

sheet rolling facilities: max. plate thickness 60 mm;

stress relieving: up to 1,250°C max. temperature;

hoisting facilities: max. capacity 80 tons;

complete laboratory for test, inspections, experimental laboratory for development and improvement of welding techniques;

complete equipment for X-ray, gamma-ray testing, ultrasonic tests, magnaflux gas leak tests, etc.

BERGUM SPA

36. This is a relatively small and recently formed company and can be considered typical of a great number of successful Italian companies which have sprung up parallel with Italy's industrial development. Bergum employs about 100 workers and is expanding at a steady rate. The shop is in the country about 30 miles from Milan, while the offices are on the outskirts of Milan. The layout of the shop (four 15 metre bays) has been designed for expansion; workspace is ample but already in the process of being doubled in length with two 30 metre bays.

37. Equipment would not appear very different to that of a typical British fabricator:
maximum cranage capacity at present is 70–80 tons;
maximum present size of products is 26 m in length and 4 m in diameter;
their present stress relieving oven is 18 m long;
typical fabrications by Bergum are vessels, LPG tanks, refinery columns and towers, heat exchangers, mainly in carbon steels and in the range of less than 2 in thick.

38. Due to competitive prices, Bergum has not experienced a lack of orders. The competitiveness is attributed to manpower productivity. Bergum has a very small non-directly productive staff. Relations between management and workers are quite direct and very good. Cost of labour is comparable to that in Britain, but there are no demarcation problems and the work force can be employed at all moments to its most productive use.

Italian pressure vessel shop layout

39. The pressure vessel fabrication shops seen and discussed in Italy varied. If the shop was quite new (say 5–15 years old) and built outside the residential areas, the advantage of long shops would be adopted. Fig. H(1) shows such a site, with three bays separated by columns rather than walls, leading into one large bay.

40. In older shops and particularly those in town areas shorter multi-bay arrangements would be adopted. The problem of material flow in such shops were reduced by moving the men rather than the materials. This was particularly true for the stages of section welding, assembly and finishing which were allowed to take place in the same part of the shop for a given vessel. It is, however, possible to say that for Italian shops, being mainly newer purpose built, more thought has been given to correct utilisation of space and cranage.

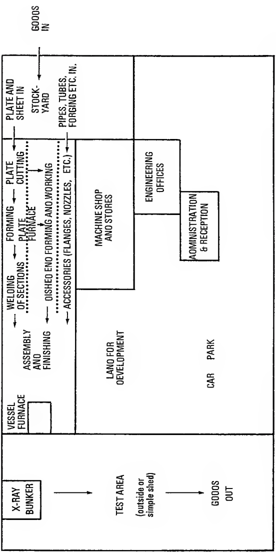
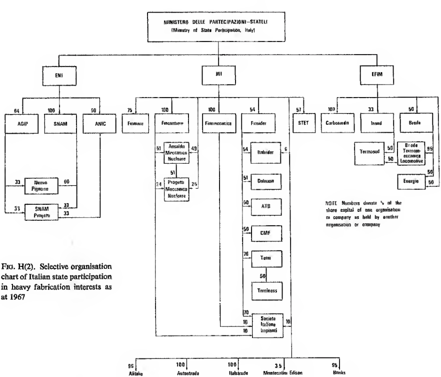


FIG. H(1). Typical lay-out of modern Italian pressure vessel fabrication site showing length and uni-directional movement of main shop (non-residential area)



NOTE Numbers denote % of the share capital of one organisation or company as held by another organisation or company

FIG. H(2). Selective organisation chart of Italian state participation in heavy fabrication interests as at 1967

The influence of state – organised industry in Italy

41. The following notes concern the influence of State participation in the process plant industry in Italy.

42. Referring to Fig. H(2), there are three main organisations with interest in the process plant industry: the Nationalised Petroleum Industry (ENI), the State-owned General Holding Company IRI (set up in 1933), and the State-owned Holding Company EFIM (set up in 1962) which has inter-alia special interests in developing the southern part of Italy.

43. An outstanding characteristic is the strong horizontal integration of the various sectors comprising these organisations. Thus FINSIDER has most, if not all, of the various steel-making plants in which IRI has an interest. Whilst strong horizontal integration has advantages in terms of rationalisation of (for example) steel production, there are also potential disadvantages through possible lack of adequate contact and information exchange between steel plants, the fabricators, the contractors and the final users (ie inadequate vertical integration). Vertical integration is becoming more important with the increase in demand for 'turn-key' plants.

44. Vertical integration exists in ENI between the contractors SNAM and the heavy vessel makers NUOVO PIGNONE, although SNAM is not tied to using it solely. Vertical integration exists in IRI in the form of steel makers supplying steel to companies within FINSIDER to fabricate vessels, but the essential contractor-to-fabricator contact has yet to be introduced (within FINSIDER). At the moment the various fabricators within FINSIDER use SNAM or outside contractors such as Foster Wheeler or CTIP. Alternative bodies that can provide a certain amount of contracting or engineering design effort are ANSALDO M. NUCLEARE in FINCANTIERE (part of IRI) and BREDA T L (part of EFIM).

45. However, FINSIDER potentially represents a very powerful complex for the complete production of 'turn-key' plants as it is already well integrated horizontally, and has one of the two main stages of vertical integration in operation (steel works to fabricator). It only remains for the final stage of vertical integration to be completed (contractor to fabricator).

46. In this respect it may be important to observe how SOCIETA ITALIANA IMPIANTI develops. This was formerly part of COSIDER and has a strong engineering design capability. Because of the interest of IRI (direct) as well as FINCANTIERE, FINMECCANICA and FINSIDER, the SII could develop into a strong chemical engineering design organisation and complete the final stage of vertical integration within FINSIDER. Should this occur, FINSIDER could become a leading industrial group in Europe in manufacturing vessels for complete chemical plant.

47. *Notes* to be read in conjunction with Fig. H(2):

ENI SNAM—contractors and chemical engineering design.
NUOVO PIGNONE—plant located near sea; makes large, heavy carbon steel vessels; has engineering design capability.

IRI ANSALDO M N—boilers, important time-to-time pressure vessel fabricator.
ITALSIDER—steel plate.
DALMINE—steel tubing (thick walled and normal), gas containers.
ATB—steel forgings, dished ends, heavy pressure vessels.
TERNI—steel plate, forgings, dished ends, heavy pressure vessels.
TERNINOSS—stainless steel plate.
SOCIETA I. IMPIANTI—engineering design, could expand into contracting.
MONTECANTINI EDISON—engineering design.

EFIM BREDA T L—boilers, engineering design, important time-to-time pressure vessel fabricator.

Fabricators in Sweden

48. Sweden's most important fabricator of pressure vessels is UDDEHOLMS AKTIEBOLAG, Degerfors, Sweden, which is part of a vertically integrated organisation. The works employ 2,200 out of the company's total of 15,000 employees. Most of the Degerfors Works' production facilities are regularly used for the fabrication of pressure vessels. The total value of pressure vessels fabricated in 1966 amounted to £2·5M. The Degerfors Works has its own facilities for the preparation of steel plate materials for pressure vessels. The laboratories are also shared with the steelworks on the same site.

49. Product range includes the following: reactor, pressure vessels, ammonia synthesis converters, high pressure autoclaves, columns, absorption towers, fermentation vessels, separators, storage pressure vessels for gases and liquids, storage spheres for compressed gases, transport tanks, pipework, etc., are regularly fabricated for the chemical, refinery, petrochemical and pulp-paper industries, etc. There is also specialisation in various types of pressure vessels for nuclear energy plants.

50. The area of Degerfors' heavy fabrication shops amounts to 236,000 ft². Cranage capacity reaches 250 tons. Stress relieving is possible for vessels up to 18′ in diameter. Plates up to 8″ thick can be formed, and dished ends can be pressed from a single plate up to 9′ 6″ diameter. Dished ends and conical parts can be built up to 26′ in diameter. Besides the most advanced welding equipment in the shop, the Degerfors Works has a welding laboratory for all necessary welding tests and all weld details for complicated fabrications. The largest annealing furnace can take charges up to 200 tons.

51. The Works is approved by Lloyd's Register of Shipping as manufacturers of Class I pressure vessels.

52. The second most important fabricator is AVESTA JERNVERKS AKTIEBOLAG, Avesta, which is a member of the Axel Johnson Group of Sweden, comprising some 20 large industrial enterprises all over the world. The group's total annual turnover amounts to about £215M with a total number of employees of about 27,000. The group's activities cover production of stainless steel, shipbuilding, heavy marine engineering, fabrication of stainless steel (150,000 tons per year), railway locomotives, general engineering contracting, etc.

53. The Avesta works fabricate steel sheets and plates, welding electrodes, tubes, valves, dished heads, castings, forgings and pressure vessels. In this last field the main products are pressure storage tanks, towers and columns, some heat exchangers and dished ends. Pressure vessels are built in all high alloy and stainless steels, and the stretched steel technique is also used. The heavy fabrication shop has 450 employees.

54. Two other enterprises of the Axel Johnson group also fabricate pressure vessels:
AB HEDEMORA VERKSTADER, Hedemora, which produces diesel engines, pulp mill machinery and pressure vessels; and
AB SVENSKA MASKINVERKEN, Kalhall, which fabricates complete steam generation plants, paper mill recovery units, firing units and marine boilers and heat exchangers and other equipment for the chemical industry. The company's capital amounts to £440,000 and has 500 employees.

55. Other significant companies fabricating pressure vessels are the following:

AB A. EKSTROMS MASKINAFFAR, Floragatan 4, Stockholm
Capital: £50,000
Employees: 90
Pressure vessel specialisation: heat exchangers.

AB EVAPORATOR, Söderköping
Capital: £75,000
Employees: 360
Pressure vessel specialisation: heat exchangers, etc.

AB GÖTAVERKEN, Göteborg 8
Capital: £5·7 million
Employees: 6,000
Activities: shipbuilding, ironfoundry, etc. Pressure vessel products: boilers, tanks and heat exchangers.

AB ROSENBLADS PATENTER, Stockholm
Capital: £75,000
Employees: 120
Activities: manufacturing of complete chemical plants and heat exchangers, contracting for industrial plant engineering. Rosenblads works in association with the Alfa-Laval Group. However, Rosenblads manufacture primarily plate type heat exchangers.

STAL-LAVAL TURBIN AB, Finspong
Capital: £2·2 million
Activities: manufacture of marine and land steam and gas turbines and heat exchangers.

AB THERMIA-VERKEN, Arvika 1
Capital: £60,000
Annual output: £2·0 million (includes all items)
Activities: pumps, heaters, compressors, heat exchangers and reactors.

Swedish pressure vessel shop layout – examples of two fabricators

56. The layout of the workshops of a large stainless steel fabricator in Sweden was very rational. There were three longitudinal bays across the top of which ran a fourth bay in which plate preparation, dished-end manufacture and pipe bending were carried out. The largest longitudinal bay was used for conventional pressure vessel manufacture; the centre bay included annealing furnaces and areas where special fabrications were made; the third bay was allocated to pipe production.

57. The works of a large mild steel fabricator in Sweden, on the other hand, was on a fairly congested site and had been built up during a number of years. The fabrication of pressure vessels was carried out in one large shop, whilst plate handling, pressing, and shaping were carried out in a separate workshop some distance away. The pressure vessel shop did not appear to be well planned, all machining was carried out in a separate area, and considerable movement of the pressure vessels during fabrication must have been necessary. The plate forming and bending shop appeared to be out-of-date, most of the equipment dating from the 1930's. Steps were being taken to modernise this section.

Fabricators in Japan

58. *Large integrated companies* are considered individually in paragraphs 59 to 92.

CHIYODA CHEMICAL ENGINEERING AND CONSTRUCTION CO., Chiyoda Building, No–3–3, 3–chome, Akasaka, Minato-ku, Tokyo
Capital: $7·5 million

59. Founded in 1948, Chiyoda has specialised in refinery and petrochemical plant fabrication and design and is one of the leading Japanese chemical contractors. It has 2,370 employees of whom 646 are mechanical engineers, 285 chemical engineers, 83 civil engineers, 91 electrical engineers, 40 instrument engineers and 15 metallurgists. Qualified scientists and engineers total 1,316, more than half the employment. The labour force include 60 welders, 40 Lloyd's Class A.

60. The pressure vessel product range includes all kinds of vessels up to 550 tons. All speciality heat exchangers, high-pressure vessels, distillery reactors and columns, rectifying, extracting and absorption towers, and all tanks.

61. Chiyoda's main pressure vessel fabricating unit, the Kawasaki factory, is equipped to handle special metals—clad steel, high tensile steel, stainless steel, nickel, copper, titanium, monel, zirconium, aluminium and non-ferrous alloys. It is recognised by Lloyd's for making Class I fusion welded pressure vessels, and by the American Petroleum Institute for storage tanks entitled to the API sign.

62. Fabrication equipment at Kawasaki can handle plate 49′ × 12′ and 100 mm thickness. The largest single unit that has been handled measured 21′ 5″ diameter, 131′ 2″ in length and weighed 150 tons. The pre-load pinch-type bending roller can cold roll plate 12′ wide and 4″ thick into a 6′ inside diameter cylinder. This roller can also form cones. There is a 1,500 ton hydraulic press that can deep draw 2″ thick steel plate cold, 12″ plate hot. A flanging machine can form end plate up to 7′ diameter or flange 21′ diameter plates of 2½″ thickness. Electro-slag welding machines can weld 2–12″ plate in one pass. Union-melt machines are used for 2″ thick seam welding in a single pass travelling at 5′ per hour for a maximum of 23′. Inspection of welds in 20″ thick plate is done by Betatron, but there are also four portable X-ray machines of 200–300 KV, Isotope Cobalt 60 and Iridium 197. The annealing furnace measures 73′×16′×16′ and can handle pieces of 150 tons.

63. Maximum pressure vessel fabrication performances are as follows:

Wall thickness	12 in
Diameter	21 ft
Length	148 ft
Weight	550 tons

64. Chiyoda has its own construction 'standards' for the fabrication of pressure vessels and other process equipment based on the Japanese construction standard and including modifications taken from such internationally recognised standards as API, ASTM, ASME, TEMA, BS and DIN.

MITSUBISHI HEAVY INDUSTRIES, 6 Maranouchi, 2–chome, Chiyoda-ku, Tokyo

65. Mitsubishi began as a shipbuilder and maker of prime movers about a century ago and now four of their yards specialise in the engineering, fabrication and construction of chemical process plant—Kobe Shipyard and Engineering Works, Hiroshima Shipyard and Engine Works, Mihara Machinery Works and Yokohama Shipyard and Engine Works. Issued corporated capital is $222M. To provide up-to-date know-how, Mitsubishi has established three technical Institutes at Nagasaki, Kobe and Hiroshima, and has three research organisations in addition at Mihara, Nagoya and Yokohama, each serving factories in those places.

66. The pressure vessel product range includes forged or monobloc steel, BASF design multi-winding, and Coilayer, a multiple layer vessel. Typical reactors recently delivered include 150 ton, 141 mm thick, 24,830 mm long × 1,830 mm diameter (material was A–336 Gr. F22, A–240 T347) and Coilayer of 430 tons 180 mm thick, 18,000 mm × 3,800 mm (material: A–204 C, HP–60 H). The Coilayer was currently offered as a hydrocracking reactor, but Mitsubishi also offered a Crawford & Russell design for high-viscosity reactions with mixer and wiper blades.

67. A 450 ton ammonia reactor had just been delivered to Alaska said to be the largest yet made in Japan, but Mitsubishi can make a 600 ton vessel and are preparing capacity to make and handle 800 ton units.

68. The following table shows the number of columns and reactors made by Mitsubishi in 1961–6:

Year	1961	1962	1963	1964	1965	1966
Columns	21	50	67	72	75	89
Reactors	57	45	68	86	70	69

69. Fabrication methods and equipment include the following: properties measured at ultra-low temperatures; overlay welding of dished ends (end plate); chemical equipment manufactured with the explosion vessel lining method; 8,000 ton bending press; overlay welding of interior metal thickness measured by smeck gauge. The company is also a significant chemical contractor.

MITSUI SHIPBUILDING AND ENGINEERING CO. (Mitsui Zosen), 2–9 Nishi Shimbashi 1–chome, Minato-ku, Tokyo

70. The company's chemical plant division, set up in 1938, realised a total turnover of $38M in 1965. The first pressure vessels were sold to Standard Vacuum in the Philippines in 1959. On 1st October 1967, Mitsui took over the assets of Fujinagata Shipbuilding

and Engineering Co., Osaka, and merged two research departments. Now Fujinagata will concentrate on plant design while Mitsui Zosen does the engineering and construction. Up to the time of the merger Mitsui Zosen employed about 10,000 people, with a R & D Department of 150, half of them graduates, in three separate laboratories, one of them now in Osaka.

71. The chemical plant division which also plays the role of a contractor, has constructed all sorts of chemical plants, including petrochemical, synthetic fibre, synthetic resin, sulphuric and phosphoric acid, and other organic and inorganic plants. It enjoys a considerable captive market due to the Mitsui Group's chemical companies.

72. The pressure vessel product range covers pressure vessels up to 200 tons with maximum wall thickness of 120 mm, 'of all weldable materials with guaranteed purity, strengths and safety'. Use of clad steels, special alloys, alloy steels and titanium is possible for all large and complicated products. Layered pressure vessels are also built.

73. The equipment includes thirty-four 3,000 ton hydraulic presses, twenty 79 × 3,000 mm bending rollers, a 600 KVA induction heater, five 12 ton welding positioners, forty-five automatic welding machines (flash butt, unionmelt, fusarc, Lincoln, etc.), a seam welder and a spot welder, a 1,000 ton forging press, thirty-three annealing furnaces 5 × 5 × 25 metres, twenty 300 KVP X-ray machines, two isotope devices, five ultrasonic flaw detectors, two metal micro-photograph apparatus, etc.

74. Annual production capacity is as follows:

Chemical plants	27,000 tons
Industrial machinery	1,000 tons
Steel structures	22,000 tons
Castings	9,000 tons
Shipbuilding	1,250,000 Tdw

MITSUI MIKE MACHINERY CO. (a member of the Mitsui Group), Mitsui Building, Nihoubashi Muromachi, Chuo-ku, Tokyo

(Capital $2·8M; Employees: 2,400)

75. The product range in chemical equipment includes: heat exchangers, tanks, reactors, towers, columns, etc. Other: mining, winding, construction, etc. machinery.

HITACHI (ENGINEERING) LTD., 4 1-chome, Marunouchi, Chiyoda-ku, Tokyo

(Capital $150M)

76. Company results 1966:

Turnover	$1,367M
Net income	$50M
Dividend	10 per cent

77. Hitachi Ltd. have many subsidiaries such as Hitachi Construction, Hitachi Shipbuilding and Engineering, etc. Basic and applied research is conducted in Hitachi's various research laboratories for plant construction and processes. There is also Babcock Hitachi K.K., a joint venture by Hitachi Ltd., and Babcock & Wilcox Ltd., England, one of the licensees of Babcock & Wilcox for the manufacture and sales of B & W boilers.

78. Hitachi's main field of experience are the following: acrylonitrile monomer, caprolactam, vinylacetate-polyvinyl alcohol, ammonia, styrene monomer, polyethylene, antibiotics, etc., plant and equipment. The company also operates as a chemical contractor.

79. Plant and equipment are mainly fabricated by Hitachi Shipbuilding and Engineering, whose capital is $50M. The main centre of manufacture for chemical process equipment is the Kasado works, equipped to make vessels up to 700 tons, 6,000 mm diameter and 60 m long, covering 'all practical pressure and temperature ranges, using almost all alloys which can be used for the chemical industry'. Maximum plate thickness is 250 mm.

80. The main equipment includes:

8,000	ton moulding press
500	ton annealing furnace
500	ton crane
25	metre pit
2,000	kilovolt X-ray inspection device
14,000	kg/cm^2 pressure-testing device.

81. The main products include:

Converter and high pressure separator for ammonia, urea, methanol, etc.;
High-temperature, high-pressure reactor for synthetic resin plants;
Ultra high-pressure reactor and separator for high-pressure polyethylene plant;
Reactor, large drum and tower for petroleum refinery plant;
Spherical tank for high-pressure gas;
Boiler drum for thermal power plant;
Pressure vessel for nuclear power plants;
Multi-layered testing vessel with design pressure of 1,800 kg/cm^2.

SUMITOMO MACHINERY CO., 6 2-chome, Nishi-Nagasu-Hondori, Amagasaki City

82. Sumitomo Machinery is, together with Sumitomo Chemical Engineering and Sumitomo Chemical Co., part of the Sumitomo Industrial Group. Sumitomo Machinery's capital amounts to $16M. Product ranges includes cranes and material handling equipment, mining machinery, machinery for steel mills, and process plant for chemical industries, especially heat exchangers. The Sumitomo Group works in close technical co-operation with BASF (Badische Anilin), the Federal Republic of Germany and M. W. Kellogg Co., USA.

ISHIKAWAJIMA – HARIMA HEAVY INDUSTRIES, New Ohtemachi Building, 2-chome, 4, Ohtemachi, Chiyoda-ku, Tokyo

(Capital: $667M; Employees: 24,000)

83. IHI was established in 1960 with the amalgamation of Ishikawajima Heavy Industries Co., and Harima Shipbuilding and Engineering Co. The total number of employees was then 16,000.

84. The following table gives data on IHI's development and structure of sales since 1961:

(million yens)

	1961	1962	1963	1964	1965
Shipbuilding	20,890	27,234	47,018	42,612	71,747
Ship-repairing	2,996	4,607	3,082	5,168	6,224
Iron and steel manufacturing and metalworking, machinery, chemical machinery	18,076	10,246	7,605	21,886	20,000
Cargo handling equipment steel structures	10,158	9,616	5,842	12,668	9,934
Boilers	7,372	7,481	7,972	4,760	7,878
Machinery for marine use	912	2,007	1,327	4,177	3,657
Aircraft engines	825	6,585	10,000	10,844	2,895
Mass-produced machinery and others	5,882	6,551	7,723	11,087	14,945
TOTAL	67,111	74,327 (+10·8%)	90,569 (+21·9%)	113,202 (+25·0%)	137,370 (+21·8%)

Source: Japan Chemical Quarterly

85. Total sales of pressure vessels, towers, columns and oil tanks amounted to $39·5M in 1965. IHI export 40 per cent of their production, mainly to Europe, the USA, South and Middle-East, Communist countries including China, Latin America and Australia.

86. Pressure vessels are fabricated in Tokyo (No. 3) Works, together with turbines, castings, chemical plants, etc., and the Aioi Shipyards' (No. 2) Works, together with diesel engines, marine boilers, chemical plants, etc. Current pressure vessel products are offered up to a 210 mm plate thickness of 10–11 m diameter and 31 m long. Practically all pressure and process temperatures are accepted. On special order, reactors with a wall thickness of 15·7″ and a diameter of 26′ are fabricated.

KAWASAKI STEEL CORP., 1 Kitahonmachi-dori, 1-chome, Fukiai-ku, Kobe

(Capital: $76M; Employees: 32,000)

87. The product range includes: high tensile strength, galvanised and stainless steel plate, etc. Heat exchangers, high-pressure vessels and head plates in the following gauge and size:

Types	Thickness (mm)	Inside diameter (mm)	Steel grades
Dish	3·2 to 70	400 – 6,000	All available in SS grade, SB grade, stainless, stainless clad, special and high tensile steels
Flat	3·2 – 70	400 – 5,800	
Hat	3·2 – 40	400 – 5,800	
Elevated bottom	3·2 – 40	400 – 5,000	
Conical	3·2 – 70	400 – 5,800	
Flange	3·2 – 70	400 – 5,800	
Jacket	3·2 – 70	400 – 5,800	
Globe	3·2 – 50	1,000 and over	

KOBE STEEL, 36 1–chome, Wakihama-cho, Fukiai-ku, Kobe

88. Kobe steel consists of 41 main manufacturing divisions. The machinery division has a large section for the manufacture of industrial machinery and equipment. All industrial divisions and sections of Kobe use the company's own products as raw materials. Kobe chemical equipment include high-pressure vessels, etc. Kobe co-operates permanently with the Chemical Construction Corporation of USA, Japan Gas Chemical Industries, and Sumitomo Chemical Co.

JAPAN STEEL WORKS LTD., Hibiya–Mitsui Building, 12–Banchi, 1–chome, Yurakucho, Chiyoda-ku, Tokyo

89. Japan Steel Works seem to be the country's leading pressure vessel constructor. Using its own steels, the company fabricates practically all sorts of pressure vessels for every industrial process, examples of which are given in the following table:

Product	Weight tons	Length	Thickness	Material	Other features
500 tpd ammonia converter	180	—	20 cm	A302B, welded forge	—
H-oil reactor	600	25 m	20 cm	Tensile strength 100,000 psig	multilayer
Hydro-cracking reactor	330	25 m	22 cm	Forging with stainless steel overlay	exported to Iran in 70-ton sections
Hydro-cracking reactor	560	25 m	20 cm	—	exported to Kuwait

90. Examples of dimensions of finished products (high-pressure vessels) at working pressure 300–350 atm are as follows:

Type	Both ends screwed and shrunk-fitted flange bolted flat cover			One end solid flange with bolted flat cover. Other end self-locking closure		
Inside diameter	900 mm (35·4″)	1,000 mm (39·4″)	1,100 mm (43·3″)	900 mm (35·4″)	1,000 mm (39·4″)	1,100 mm (43·3″)
Total length	18,000 mm (709″)	17,500 mm (689″)	13,800 mm (543″)	17,500 mm (689″)	16,500 mm (650″)	13,500 mm (531″)
Capacity	11·4 m^3 (403 ft^3)	13·0 m^3 (459 ft^3)	13·2 m^3 (466 ft^3)	11·0 m^3 (388 ft^3)	12·0 m^3 (424 ft^3)	12·8 m^3 (452 ft^3)

Source: Japan Steel Works

91. Present maximum range of pressure vessels fabricated by Japan Steel Works contains all sizes up to 660 tons, with a maximum diameter of 224″.

92. The only data available on equipment are the following:
600–ton crane
10,000–ton hydraulic press
Betatron inspection equipment

93. *Other significant pressure vessel fabricators* are given in Table H(6).

TABLE H(6)
Significant Japanese pressure vessel fabricators

Name of company	Capital US $M	Product range	Pressure vessel specialisation
Daiki Eng.	—	Machinery and plant for chemical industry	H-PV, lined with stainless steel, etc.
Fuji Car Mfg.	3·5	Rolling stock, chemical equipment, etc.	H-PV of various kinds
Hirakawa Iron Wks.	—	B, PV, T, etc.	—
Hirano Iron Works	0·5	Chemical equipment	B for marine use, HE, PV
Hisaka Works	0·8	Pumps and chemical equipment	HE
Hokkai Iron Works	—	Tanks, forgings, etc.	H-PV, HE, T: Dished and flanged type heads
Ishi Iron Works	3·0	Forgings, refining plants, etc.	HE, etc.
Kawasaki Rolling Stock Mfg.	6·1	Rolling stock, milling machines, machinery for chemical and textile industry	H-PV
Kotobuki Industry	1·0	Machine tools, milling machines	HE
Nihon Joryu Kogyo	0·5	Chemical equipment	HE
Nippon Kokan Kabushiki	230·0	Iron and steel, tubes, sheets, coal chemicals, fertilizers, shipbuilding, all industrial plants, etc.	PV, H-PV
Nihon Kentetsu	2·8	Construction metal production; electric machinery, etc.	HE, etc.
Nippon Sharyo Shizo Kaisha	6·2	Rolling stock, construction and mining, chemical equipment	H-PV, forgings
Nisso Steel Mfg.	8·4	Iron and steel machinery	HE
Osaka Boiler Mfg.	—	Marine boilers	PV
Oye Chemical Mach. & Equipment	1·0	Chemical equipment, pumps, etc.	PV, HE, T: stainless steel titanium
Sasakura Eng. & Mach.	0·3	Distillation plants, etc.	HE
Takao Iron Works	0·2	All kinds of land boilers	HE, PV
Takuma Boiler Mfg.	4·0	Water purification plants; chemical industry machinery, conveyors	HE, B
Tamagava Metal & Machinery	2·8	Metal sheets, stainless tubes, pipes, die casting, chemical equipment	HE
Tokyo Chemical Engineering	0·3	Sugar refining plants; oil and fat plants	HE
Yokohama Eng. Co.	2·8	All kinds of boilers	—
Uraga Heavy Industries	18·0	Ships, prime movers, pneumatic, hydraulic chemical equipment	PV, HE

Note: PV =pressure vessels
H-PV=High-pressure vessels
B =boilers
HE =heat exchangers
T =tanks

94. Although no data on equipment could be obtained for pressure vessel fabricators listed in Table H(6), it is estimated that most of them are capable of making vessels of 100 tons. Many in this group of fabricators are in reality either specialised divisions of large companies, more or less integrated, or belong to significant company groups.

The position of the Mitsui, Mitsubishi and Sumitomo groups

95. The position of three giants of the Japanese industry—the Mitsui, Mitsubishi and Sumitomo groups—is given separate consideration. These three groups, together with groups headed by the Industrial Bank of Japan, the Fuji Bank and the Dai-Ichi Bank, have in their hands 62 per cent of the Japanese mining industry, and 76% and 65% of the country's metallurgical and mechanical industries respectively.

Activity	Mitsui per cent	Mitsubishi per cent	Sumitomo per cent
HEAVY AND CHEMICAL INDUSTRIES	30·4	54·0	62·5
of which: shipbuilding	5·0	24·3	—
metallurgy and mechanical	7·7	16·9	47·0
chemical industry	18·1	12·9	15·5
FINANCE (banking and insurance)	14·6	12·9	15·8
OTHER ACTIVITIES (industrial and service)	55·0	33·1	21·7
TOTAL	100·0	100·0	100·0

Source: Oriental Economist

96. The type of integration within the three groups is mainly financial—as generally in most sectors of Japanese industry. The extent to which the capital of the groups' main enterprises is held within each group illustrates as follows the financial character of their integration.

97. The rate of group's holding, ie per cent of capital of the principal member companies held by each group:

	Mitsui	Mitsubishi	Sumitomo
No of enterprises in each group	20	22	14
Rate of holding by group (%)	15·6	21·7	27·2

98. The role of the country's main banks and other financial institutions is very important: their share in the total participations of the three groups is the following:

Mitsui	60·4 per cent
Mitsubishi	71·0 per cent
Sumitomo	48·5 per cent

Recent development shows, however, a tendency towards a greater independence with regard to the banks and also to the Bank of Japan.

APPENDIX G

Need for customs and other statistical data on pressure vessels

1. The absence of statistical information on various economic aspects of the vessel industry became apparent at early meetings of the Committee of Enquiry. Two examples are given in the present Appendix whereby improvements in the availability of statistical data either have occurred (the customs data) or are recommended (the trade journal data).

2. The first example related to the absence of detailed customs data on the import levels of pressure vessels and similar fabrications. The Custom and Excise import and export statistics had been improved as from January 1968 by the introduction of new statistical headings to cover heat exchangers, process pressure vessels (including distillation columns and reactor vessels) for mineral oil refining and process pressure vessels for other purposes. As a result it could now be stated that there is adequate information on imports and exports in respect of pressure and other vessels.

3. The second example related to the lack of adequate data either on past UK investment in chemical plant or on UK fabrication output. It is believed that up to 1967 the only sources of information available on investments were:

(1) the Board of Trade estimates for capital expenditures at industry level;

(2) the Chemical Industries Association survey of chemical investment at aggregate level;

(3) the *Chemical Age* survey of the chemical industry and of contractors' activity at chemical sub-sector level.

4. These sources could be improved to give the following data:

(1) the distribution of capital expenditure by:
  (a) hardware or equipment expenditures;
  (b) plant-erection or site expenditures;

(2) the breakdown of the chemical industry figures to sub-sector levels;

(3) the collation of information relevant to capital sanctions and the ensuing time distribution of capital expenditures (ie expenditure data should give some indication as to the sanction data from which it arose, as well as the timing at which the expenditure fell);

(4) the collation of information relevant to contractors' activity on a yearly basis at sub-sector level. Background data concerned with contractors' mark-ups and payment schedules between contractor, final user and equipment supplier (timing and percentage of total costs) might also be provided if possible.

5. The information existing in 1967 was considered to be unreliable. The methods of data collation as well as the data collected could be considerably improved to supply the above disaggregated information. For example, the valuable records of plants constructed as compiled by *Chemical Age* could be improved further. *Chemical Age* received annual returns *direct* from contractors and manufacturers; this represented an important set of data because it is essentially 'primary data'. The various investment data published in *Chemical Age* might be defined more accurately, so that a very accurate description could be given to all items included in the investment data. Thus work in hand as published could mean either orders received during one year or *all* orders in hand including those still-in-hand and carried forward from the previous year(s). The possibility of double accounting and other sources of error were evident with present arrangements.

6. At the same time, fabricators' or equipment suppliers' information might be considerably improved.

APPENDIX H

The position of the UK pressure vessel industry during 1967

1. During the spring and summer of 1967 the Committee became very concerned that the level of new orders coming into the pressure vessel industry was then disturbingly low. They drew the attention of the Minister of Technology to this in a letter dated 20th June, 1967. They recounted that up to the end of 1966 the industry had passed through a period of unprecedented demand arising from the chemical industry, the gas boards, the electricity boards, the oil refining industry and others. The demand in all of these industries appeared to have decreased *simultaneously* so that many fabricators' works were desperately short of orders.

2. As a result of this letter, representatives of the Committee met the then Joint Parliamentary Secretary (Mr. E. Dell, MP) in July, 1967 and presented the following observations:

(a) The Mechanical Engineering EDC short-term trend report for May 1967 reflected the down-turn in new orders in the process plant, boiler and pressure vessel industries;

(b) Information obtained from BCECA, of contracts to be awarded for process and other plant in the near future, indicated a similar trend. A single major chemical company only planned capital expenditure in 1967 at about half the level of its capital expenditure in 1966;

(c) Data obtained from TIPA gave figures for reduced order-book intake into pressure vessel shops, by direct contact with 13 member companies representing 22% of UK shop-built pressure vessel output;

(d) Evidence was given of the pronounced cyclic variation in the loading of the pressure vessel industry, including information on the demand and supply of dished ends from a major dished-end manufacturer as shown in Fig. H(1);

(e) An interval of 6 months or so commonly occurred between the placing of orders for the main plant and the arrival of work on the fabrication shop floor. This affected greatly the validity of some of the then contemporary estimates of shop loading in the pressure vessel industry.

3. A number of suggestions for actions to alleviate the situation were made at the meeting in July and during subsequent correspondence. However, during August and September the Committee received further reports of continuing and increasing difficulties due to low order-intake in the pressure vessel industry, including further reports of laying off labour. The down-turn of new orders on fabricated steelwork including pressure vessels was emphasised in the Mechanical Engineering EDC short-term trend report of August 1967. In view of these reports, a further meeting was arranged between representatives of the Committee and the appropriate Joint Parliamentary Secretary, who then was Dr. J. Bray, M.P. At this meeting (9th November 1967) various possible remedial actions were discussed.

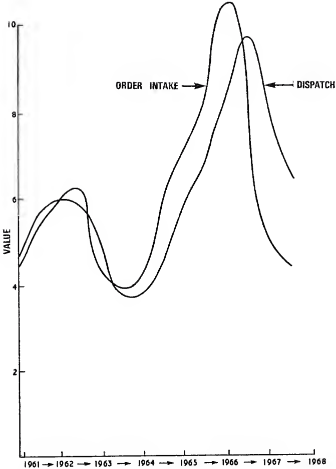


FIG. H(1). Demand and supply curves for dished and flanged ends from one UK manufacturer

APPENDIX J

Limitations on size and weight for road and other transport

1. It is likely that as the average size of chemical plants and oil refineries continues to increase in the future, so will the average size and weight of pressure vessels.

2. Oil refineries may require pressure vessels in the future between 350 and 450 tons in weight and with 10 inch wall thicknesses. (Tentative estimates in the growth in weight of transformers would raise the present maximum weight from 300 tons to 400 tons in 10 years time and 450 tons in 20 years time).

3. In para. 3.15 of Appendix F is given a table of the number of UK fabricators (with shopbuilt pressure vessel outputs greater than £0·2M in 1966) that can build vessels within certain maximum weight ranges. A summary table is given here for reference:

Maximum weight of vessel that can be built	*Number of UK fabricators*
101–150 tons	5
151–200 tons	5
201–300 tons	2
300+ tons	3

4. From this table it may be seen that 15 fabricators in the UK (with shopbuilt pressure vessel outputs greater than £0·2M in 1966) can build vessels with a weight over 100 tons, and 3 fabricators vessels with a weight over 300 tons.

5. Transport costs for pressure vessels as a percentage of value per ton (about 10%) are considerably higher than those for other classes of engineering goods such as transformers. Pressure vessels (excluding those in stainless and other special steels) sell for approximately £100 to £400 per ton, whereas transformers sell for approximately £1,000 to £1,500 per ton.

6. Pressure vessels may be transported by rail where the maximum height or width does not exceed 14 ft; it is usually recommended that long, thin vessels over 90 ft in length be carried by rail.

7. For purposes of carriage by road, the Ministry of Transport has classified loads according to the following:

(a) Divisible Loads, Gross Vehicle Weight up to 32 tons;

(b) Indivisible and Abnormal Indivisible Loads, Gross Weight up to 150 tons;

(c) Special Permission: Ministry of Transport, Gross Weight up to 300 tons;

(*Note:* there are two roads in the UK with a maximum weight limit up to 300 tons)

8. In respect of divisible loads, the maximum permitted weights and dimensions for road vehicles used for the carriage of normal divisible goods are laid down in the Motor Vehicles (Construction and Use) Regulations 1966, as amended. Briefly they are as follows—the recently altered articulated vehicle and draw-bar trailer lengths being effective from 8th April, 1968:

Maximum dimension	Articulated vehicles	Rigid vehicles	Trailers (but not trailers forming part of articulated vehicles)
Gross weight	32 tons	28 tons	28 tons
Axle weight	10 tons	10 tons	10 tons
Wheel weight	5 tons	5 tons	5 tons
Length	15 metres	11 metres	12 metres
Width	2·5 metres	2·5 metres	2·5 metres

Rigid vehicle/trailer combination maximum: Gross 32 tons
Length 18 metres

9. The overall width of a divisible load must not exceed 9 feet 6 inches, while length is generally limited to the platform length of the vehicle although loads are permitted to overhang both to the front and rear but specified conditions must be complied with when this exceeds a few feet. Weights and dimensions shown are in some cases subject to conditions specified in the Regulations.

10. Certain loads, and some large pressure vessels are among these, which cannot without undue expense or risk of damage be divided into two or more loads and which cannot be carried on a vehicle complying with the Construction and Use Regulations (ie 'indivisible loads' and 'abnormal indivisible loads') are permitted to exceed the above maxima but are subject to the conditions and restrictions of the Motor Vehicles (Authorisation of Special Types) General Order 1966. The maxima here are length 90 ft, width 14 ft and gross weight 150 tons.

11. When the maxima in para 10 are exceeded, and also when the width exceeds 14 feet, special permission is required from the Ministry of Transport. This is only granted if a suitable route is available and the Ministry is satisfied that no other form of transport is practicable. There is no statutory limit on the height at which a load can be moved by road. The limits on height are physical ones imposed by overbridges (new bridges are normally constructed with a 16′ 6″ minimum clearance), overhead cables and similar obstructions.

12. The Ministry of Transport has been asked by industry to increase some of the maximum weight limits in the Construction and Use Regulations. Such increases would raise problems particularly in relation to bridge strength. Ministry of Transport bridge engineers have been working on a reassessment of bridge strengths and once this work has been completed the Ministry would be reviewing the weight limits generally.

13. The National Ports Council set up in 1967 a 'Working Party on the Movement of Heavy Indivisible Loads' to examine present methods of moving abnormal loads through the points of exit and entry in the UK, including improved road access and heavy lift

facilities at ports, dockyards and shipyards. For purposes of the survey on lifting facilities carried out by the Working Party, an abnormal load is not less than:

90 tons weight net, or
90 ft length external, or
14 ft width external, or
14 ft height external

14. It is noted in the Economic Survey (Appendix F to this Report) that Japan had already built pressure vessels of 600 tons weight. This was achieved by building the vessels on the seaboard on sites normally used for constructing ships. On-loading the vessel to a ship presented no undue problem with the availability of floating cranes with between 500–1,000 tons lifting capacity. It is possible that vessels weighing over 300 tons (excluding site-built vessels) in the UK may most conveniently be built on the seaboard rather than inland.

APPENDIX K

Aids to exporters

1. One of the major findings of the economic survey was the forecast that the UK home demand for pressure vessels will probably not exceed that in 1966 during the next decade, and the conclusion was drawn that for the UK pressure vessel industry to expand output in the future it would need to sell more pressure vessels abroad. The two routes to overseas sales are either direct sales from the fabricator to the final user or contractor abroad, or indirect sales by selling to the UK contractor for inclusion in a 'package plant' overseas. In 1966 direct sales were about 20% of total exports while indirect sales were 80% of total exports.

2. Whilst many reasons may be forwarded or excuses proposed as to why a greater amount of vessels were not exported (direct or indirect) one reason which may not be so forwarded is lack of knowledge of export facilities and procedures. There is an abundance of guidance on exporting available in the UK, and several of the more important examples are given in this appendix to illustrate this fact.

3. The Board of Trade has published several export handbooks describing fully the facilities they can offer to those wishing to promote their products in the export market. Export Handbook No. 1 'Services for British Exporters' details the various parts of the Board of Trade, under the general heading Export Intelligence, that can provide valuable help. These include the Export Services Branch (market assessments, specific sales opportunities, the journals 'Export Service Bulletin' and 'Board of Trade Journal', tariff and import regulations, sales agents abroad, commercial standing of companies overseas, overseas business visits, export partnerships); the Statistics and Market Intelligence Library; Overseas Trade Fairs Directorate; Overseas Publicity, etc.

4. The Export Handbook No. 2 'ECGD Credit Insurance and Financial Support Services' describes in detail the facilities for credit insurance available from the Export Credits Guarantee Department. The services provided by ECGD include consideration of the amount of credits available and their terms, interest rates and durations, as well as the methods of selecting those deals on which credit insurance would be granted.

5. The Export Handbook No. 3 'Organisation for Overseas Marketing' describes how UK companies may reorganise so as to become 'export-orientated'.

6. In summary, the Board of Trade's Export Intelligence services provide a great deal of help for exporters, much of it free. This includes:

Guidance on individual export problems
Information on the most likely markets for products overseas
Introductions to potential agents and buyers
Help with overseas business visits
Status reports on foreign companies
Information on tariff and import regulations
Details of overseas contracts out for tender

Help and advise on participating in trade fairs overseas
Assistance in finding licensees to manufacture products abroad
Information on how to market and publicise products abroad

7. The Central Office of Information (COI) may provide help with its world-wide publicity network available through Embassies, High Commissions and other similar posts abroad. The COI may prepare and distribute material in professional format to the press, radio, television and cinemas overseas.

8. The BBC External Services broadcast throughout the world, and an important part of their output deals with developments in British industry, science and technology.

9. The British National Export Council (BNEC) provides overseas facilities for bringing trade opportunities to the notice of exporters; for seeking new openings for the sale of British goods and services; and for encouraging and supporting organisations able to foster a favourable climate for British exports. Furthermore, substantial financial aid (50%) is available for both inward trade missions (foreign buyers visiting the UK) and outward trade missions (UK sellers visiting overseas). Full information is available, together with much useful advice on trading abroad, in their booklet 'Trade Missions—Do's and Don'ts'.

10. HM Customs and Excise can help with certain specialised aspects, such as relief from duties paid for imported goods used ultimately for re-export, and other aspects.

11. The Market Research Society can provide a list of its members' organisations in the UK who can carry out market research surveys for various markets at home and abroad.

12. The Confederation of British Industry (CBI) has a CBI Overseas Directorate which maintains a network of contacts abroad to maintain the flow of inward marketing and other information; all this is publicised regularly in its 'Overseas Trade Bulletin'. There are also various Committees dealing with policy matters on: Overseas (General); Overseas Investment; and Export Credits.

13. The British Export Houses Association can provide information on the specialised exporting services available from the various specialist UK export houses.

14. Export education is available from local authorities and independent bodies, including the Institute of Export.

15. Export clubs are in existence throughout the country, and are informal associations of local manufacturers for the exchange of advice and experience on overseas markets and export procedures and co-operative exercises in trade missions and overseas exhibitions (information on these from Board of Trade).

16. Direct financial incentives specifically for exports are:

(a) Help with overseas trade promotions (through Board of Trade) for:

Joint Venture Scheme for exhibits at specialised fairs or in specialised sections at general fairs;

British pavilions at some international trade fairs;

All-British trade fairs showing only British products;

(b) Co-operative advertising scheme (through Board of Trade) for companies using paid advertising for overseas trade promotions;

(c) Trade missions (through BNEC) for aid towards both 'inward' and 'outward' trade missions;

(d) Market research (through BNEC) for aid towards market research surveys overseas;

(e) Aid for directories (through BNEC) for aid towards foreign trade directories and buyer's guides;

(f) Drawback and other schemes concerning duties on certain imported goods and materials used in the export trade (through HM Customs and Excise).

17. The Technical Help to Exporters Section (THE) of the BSI is organised to provide comprehensive technical help to exporting manufacturers. Part of this service is provided by the Technical Digests and part by assistance to individual manufacturers on their specific problems. Technical Digests relating to design standards, statutory requirements, inspection and approval procedures, are available for the following countries: Belgium, France, Federal Republic of Germany, Holland, Italy, Republic of Ireland, Luxembourg, Norway, Portugal, Sweden and Spain. Another dozen digests are in preparation or in print. THE also has copies of the original design standards of most foreign countries, including in many cases translations into English of these foreign standards.

18. There are also many articles in the technical, commercial and industrial press on hints towards sales success on export markets. For example, Elliott Flight Automation have published their successful selling methods (on selling in the very competitive USA defence systems market) in 'Flight International' of 29th February, 1968.

APPENDIX L

Surveys on materials and steel supply: summary report

Part I. Questionnaire to the fabricators

1. The subject of materials used in the manufacture of pressure vessels was one of the topics raised in the response to the General Enquiry Letter circulated in February 1967 (See Appendix E). It was considered that many of the comments received were of a generalised nature and that further evidence should be sought. Accordingly, a questionnaire was prepared to obtain specific answers to a series of direct questions and this was circulated to the appropriate Trade Associations who arranged for their members to receive copies. Altogether 26 fabricators and trade associations responded to the questionnaire. The 'Questionnaire on Materials for Pressure Vessels' is attached at Annex A to this Appendix.

2. The following analysis is given of the replies to the questionnaire. No attempt has been made to weigh the various respondents' views in terms of company output or any other factor. These are, however, taken into account in the discussion of the results of the questionnaire in Chapter 8 of the Report.

RATIONALISATION OF STEEL STANDARDS (*Question* 1)

3. An analysis of the replies to Question 1 reveals that 26% of the respondents felt that the new standards, including those in draft form, now provide the rational series that had been sought. A further 50%, whilst accepting that the new standards represented a major step forward in rationalisation, pointed out gaps in these standards, eg proprietary steels, low alloy steels, stainless steels and special steels such as 9% Ni, Hi-proof stainless and stainless maraging. There was also criticism of the length of time taken to produce standards and that these did not appear sufficiently quickly after the introduction of a new material. The remaining 24% felt the situation was unsatisfactory for a variety of reasons, eg general confusion existing at the moment regarding BS 1501–1506, absence of reliable stress data in the standards, difficulty in understanding the system of nomenclature covering the austenitic stainless steels, differences existing between the standards which specify pressure vessel material and those that specify material for high pressure pipe assemblies.

CHEMICAL COMPOSITION (*Question* 2)

Carbon and Manganese

4. Approximately 60% of the respondents considered that the C and Mn content ranges in the various specifications were generally satisfactory and that it was more important to stabilise the mechanical properties of the material over a range of section sizes. However, 30% felt that the composition ranges should be more closely controlled in order to define welding and hardening procedures with more precision. An interesting observation from a major fabricator was that the specifying of composition on the basis

of maximum values for individual elements was unsatisfactory taken in isolation. Segregation effects within casts, as well as cast to cast variation, lead to situations where welding techniques must be stipulated which cater for the worst case and hence are uneconomic in material usage. Specifications should be based on ladle and check analysis together with statistical or other information related to actual composition limits for each specification and product form. This information should be supplied by steelmakers as part of the normal technical sales service which any buyer had the right to obtain.

Sulphur and phosphorous content

5. 30% of the respondents considered that the present levels of S & P were acceptable; the remaining, however, wanted a reduction to a figure ranging from 0·015% to 0·04%. There was also a suggestion that a minimum sulphur content be specified to avoid increased susceptibility to hydrogen cracking.

Trace elements

6. There was a general feeling that existing specifications adequately specified trace elements, although there was a qualification that if a maximum carbon equivalent was included in the specification this would be an additional safeguard against an unduly high content of elements like Ni, Cr and Mo.

STEEL AVAILABILITY (*Question* 3)

Availability of special steels

7. 70% of the respondents considered that there were delivery difficulties with special steels; the complaints being confined largely to stainless clad and 9% Ni plate and to plates with special features of thickness, width or total weight.

Availability of standard steels

8. 55% of respondents considered that there were delivery difficulties with standard steels and to an extent this varied with industrial activity. There was a complaint that steels available ex-stock were not usually fully certified and that certification involved long delivery and an extra charge. A frustrating source of delay was that when a single plate in a hatch was rejected a replacement took a long time to obtain.

Range of British steels

9. 70% of the respondents considered that the range was adequate providing proprietary steels were taken into account; there was general welcome for the progress being made in extending the scope of BS to cover proprietary steels. There was complaint, however, of the price differential in respect of exported steel which benefited foreign fabricators in competition with British fabricators.

CLEANLINESS (*Question* 4)

Cleanliness and laminations

10. Of the 26 organisations questioned only one stated that the standard of cleanliness was adequate for its purposes. 50% registered major complaints covering laminations,

poor surface finish and cracks and 45% suffered intermittent problems in the same areas. Two respondents had experience of foreign steels; one considered that the surface finish of plates from Continental makers was generally superior to that of plates from their British counterparts whilst the other considered that experience with British and foreign steels was essentially similar. There was also criticism of the limited capacity available for electric furnace or vacuum degassed steels, both of these processes producing cleaner steel.

Ultrasonic testing

11. Only 10% of the respondents specified ultrasonically tested plates from the steel supplier; the remainder carried out their own ultrasonic inspection unless the customer specifically requested mill testing. The increase in price of plate by 20% for mill testing was considered a high premium for ultrasonic inspection. There was in general little difficulty in interpreting the results of ultrasonic inspection, but there was a need for a British Standard based on a closer grid pattern than the HSA specification.

NON-STANDARD STEELS AND SPECIAL FEATURES (*Question 5*)

Foreign specifications

12. 60% of the respondents considered that British steelmakers were reluctant to accept orders to foreign specifications for small quantities of steel; it being appreciated that quantities less than a complete melt were economically unattractive to the steelmakers. It was nevertheless felt that the extra charge in some cases was exhorbitant.

Ultrasonic testing

13. There was a consistent complaint throughout the submissions of the 20% premium charged for ultrasonic inspection to ensure that the steel had an adequate standard of cleanliness. This was seen in marked contrast to foreign practice, particularly in the Federal Republic of Germany and Japan where special plate steels are vacuum degassed and ultrasonically tested without this high premium.

Impact testing

14. There was some comment (from 4 organisations) about the extra charge for impact tests and the point was made that in most cases the Continental price was inclusive of the tests specified in the standard.

STEEL PROPERTY DATA (*Question 6*)

15. It was difficult to quantify the information given in the replies from the 18 organisations which responded to this question. To the extent to which any gaps in the data have been identified they are summarised as follows:

(a) Elevated temperature proof stress properties in the temperature range 50–250°C;

(b) Elevated temperature property data for low alloy steels;

(c) Elevated temperature property data for austenitic steels;

(d) Elevated temperature property data for specific component forms (ie very thick plates, forgings, pipes).

SPECIFICATION OF MINIMUM PROPERTY LEVELS (*Question 7*)

16. If a high confidence level is used in assessing minimum values, then these will be lower than published Continental values. However, these accurate values should allow lower safety factors to be used. Alternatively, if the current safety factors are to be maintained, then it is necessary to lower the confidence level of the minimum property in order to get design stresses comparable with Continental practice. Question 7 asked whether lower confidence levels or lower safety factors were preferred. Since this is a highly technical question simple answers which could easily be summarised were not to be expected. To the extent that a preference has been given between these two alternatives, the following summary is given:

Respondents preferring a reduction in safety factor . .	4
Respondents opposing a reduction in safety factor . .	6
Total number of respondents to this question . . .	17

17. Of the respondents opposing a reduction in safety factor, three had no alternative suggestion to make. The other three commented as follows:

(a) Opposed until international agreement can be reached on safety factors—in the meantime favour 'trend curves' to adjust property values;

(b) Opposed until international agreement can be reached—in the meantime to adjust property values 'perhaps by the choice of confidence limits';

(c) Opposed until international agreement can be obtained.

OTHER ASPECTS (*Question* 8)

18. One of the main problems existing in the pressure vessel industry concerns the case of very thick plates and heavy forgings for high pressure vessels (ie ammonia converters) and what value can be placed on results obtained from representative test pieces from these. It is felt that not enough is known about the effect of mass, ie the effect of section thickness on the behaviour of steels.

19. Invariably new materials and even existing ones have their properties analysed in great detail, but the properties of equivalent weld metals and associated welding procedures are not so clearly defined.

20. Difficulties have been found in obtaining deliveries of tubes and tubular fittings such as elbows.

21. One of the main obstructions in the way of rapid introduction of new steels into the pressure vessel industry is the ultra-cautious attitude of British insurance companies, coupled with the length of time required to produce new standards.

22. The present attitude of British steelmakers towards replacement of faulty material: more often than not faults are not revealed until much work had been expended by the fabricators. No compensation is forthcoming, in most cases, for the man or machine hours expended in processing the faulty material by the fabricator.

23. The low temperature properties of steels in the welded state are considered to be of vital importance to the pressure vessel industry. Fullscale crack initiation and propa-

gation tests are needed. Serious consideration should be given to the type-testing of steels as currently practised in Japan, with a view to having steels tested and approved.

24. If British steels were cheaper and had better impact properties down to —50°C there would be reasonable satisfaction.

Part II. Questionnaire to the UK steel industry

25. On the basis of the information received in replies from the pressure vessel industry (see Part I of this Appendix) it was decided to prepare a questionnaire to be sent to steelmakers, to obtain their comments on the views expressed by steel-users. The questionnaire was sent directly to the steelmakers known to be involved in the supply of steel to the pressure vessel industry and also, through the BISF, to the various conferences which deal with the different product forms ie plate, sheet, alloy steel, forgings. Altogether 12 steelmakers' trade associations and conferences and steel companies replied to the questionnaire. A copy of the questionnaire is attached at Annex B to this Appendix.

26. The nature of the questions in the questionnaire and the replies subsequently received did not lend themselves to a comparatively straightforward analysis as was the case in Part I. Instead, a summary of the views of the steelmakers against each question in the questionnaire is provided.

BRITISH STEEL STANDARDS (*Question* 1)

27. In the first submissions in response to the General Enquiry Letter (Appendix E) there was general criticism of multiplicity and overlap of British Standards resulting in an urgent need for rationalisation. These comments appeared to ignore the work that was in progress to produce revised versions of BS 1501, 1502, 1503, 3059, 3602, 3604 and 3605. Consequently, in the questionnaire to fabricators (Part I) special attention was directed to these Standards and further comment was requested. The answers given showed there was general agreement that these standards represented a rational series, but there was some criticism of the delay in completing them and complaints about notable omissions such as proprietary steels, stainless and 9% Ni steels. These aspects were put to the steelmakers and they were specifically asked to give reasons for the delay in issuing these standards (covering the seven years that the relevant ISE/62 committees had been working).

28. The answers given by the steelmakers centred around the limited demand for some of the special steels such as 9% Ni; the fact that BSI Standards for proprietary steels were not permitted until 1965; and the fact that some were not regarded as having very high priority. There was however some very positive comment about the delays which occurred in producing a standard after the initiation stage. From the comments, it appeared that there had been two years' delay following the initiation of work on steels like the proprietary plate steels, 9% Ni and low alloy steels. The delay was attributed to insufficient BSI staff; to unnecessarily long intervals between meetings; the cumbersome procedure of large unwieldy committees; and to the fact that the recommended Bowlby procedure for immediate circulation of draft proposals had been ignored. They recommended that a separate standards procedure should be introduced

for steels; that there should be an automatic review of steel standards every three years; that there should be closer liaison between committees dealing with design and with material standards; and that the staff at BSI dealing with steel standards should be increased.

RANGE OF STEELS AVAILABLE (*Question* 2)

29. One of the points made in the original submissions (Appendix E) was that the range of steels available to the British pressure vessel industry was less than in other countries and this particularly applied to higher tensile and quenched and tempered steels. When these questions were put more precisely in the questionnaire to fabricators (Part I), the answers showed there was reasonable agreement that the range was adequate, providing proprietary steels were taken into account and providing that these were included in national Standards, that they were reasonably priced, and that there were no delivery delays.

30. The Steelmakers' answers maintained that the range was adequate and quite comparable with that available in Germany. They compared the properties of both standard and proprietary steels and showed that the British steels were directly comparable. They drew attention to the fact that one of the most attractive British steels on a price/design strength basis was BS 1501–213 and yet this was little used by the pressure vessel industry. It was accepted that to obtain an adequate range of properties it was necessary to use proprietary steels, but it was suggested that this was a natural stage in the development of steels. The steelmakers recommended that British Standards procedure should permit the use of a proprietary steel on a tentative basis, without the necessity for the tedious consideration by the standards committee. Such a steel would only be submitted for the full British Standard acceptance when it could be shown that there was an established demand for the steel.

31. In support of the view that British standard steels were comparable with those obtained in Germany, a comparison was made by the Steelmakers of the design stress range available to the British pressure vessel maker using British standard steels with that of his German counterparts using German standard steels. German steels were selected for comparison purposes because these are generally the ones which British pressure vessel makers quoted when questions of inadequacy of the British range of steels are raised. The comments in paragraph 32 are extracted from the evidence submitted.

32. The attached Figs. L(1 & 2) show the design stress range available to British and German pressure vessel makers using standard steels. Figs. L(1 & 2) are to the same scale so that direct comparison can be made. It will be noted that the German carbon and carbon manganese steels cover a very similar range to the comparable British steels, with the exception of 19MN5. However the British BS 1501–213 Grade 32B steel adequately matches the 19MN5 range. It is interesting to the British steelmakers that very little use has been made of the BS 1501–213 steel by the British pressure vessel industry, despite the fact that on a price/design strength ratio basis this steel is the most attractive among the British standard steels. The fact remains therefore that the tonnage of pressure vessel plate supplied lies in the less attractive BS 1501–151 and 161 grades.

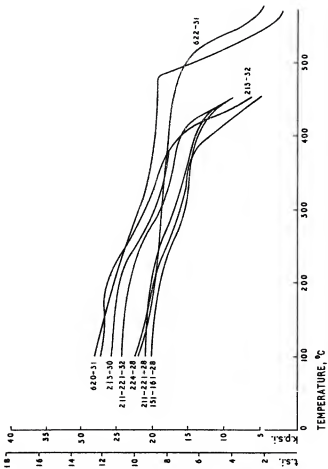


FIG. L(1). Design stresses for British standard steels under BS 1515:1

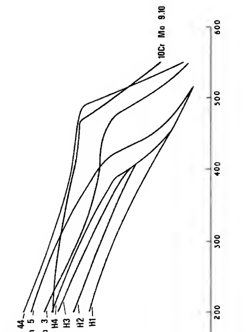


FIG. L(2). Design stresses for German standard steels under AD—Merkeblätter

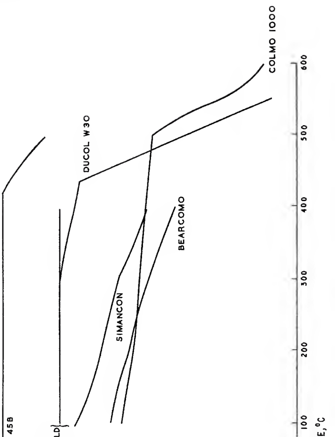


FIG. L(3). Design stresses for British proprietary steels under BS 1515:1

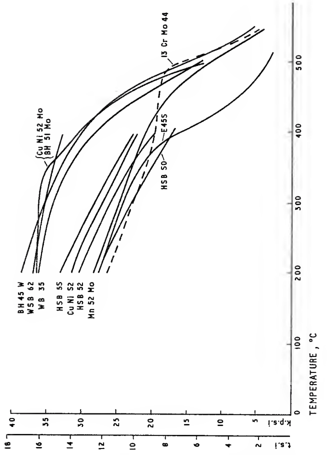


FIG. L(4). Design stresses for German proprietary steels under AD—Merkeblätter

33. A comparison was also made by the steelmakers between British and German proprietary steels. Fig. L(4) presents a selection of German proprietary steels and Fig. L(3) the British. Comparison between Figs. L(2) and L(4) show that the German standard and proprietary steels together form a continuous series over a wide range of design stresses. On the same basis the British steels (Figs. L(1) and (3)) show a similar range of design stresses, but a lower density or population for the proprietary steels.

34. A subsidiary question asked whether orders to foreign specifications were accepted and if so, whether this involved an extra premium or delivery time. In general, the answers indicated that foreign specifications were accepted on the same basis as British specifications and did not involve a premium or long delivery period. It was mentioned that certain minimum quantities would be necessary and that there was less likelihood that any stocks would be held.

STEEL SUPPLY (*Question* 3)

35. In response to question 3 the following figures were given for the supply of pressure vessel steel plate by four major UK makers in 1966:

Maker	C and C–Mn steels (tons)	3½% Ni and 9% Ni (tons)	Proprietary steels referred to in question 3(iii) of questionnaire (tons)	Low alloy steels, e.g. ½% Mo; 1% Cr ½% Mo; 2¼% Cr 1% Mo (tons)
1	52,159	—	1,682	574 (½% Mo)
2	70,000	35	3,950	5,400
3	25,000	410	2,650	50 (½% Mo)
4	35,462	Nil	Nil	702 (½% Mo)
TOTALS	182,621	445	8,281	6,726

36. The figure of 182,621 tons for C and C-Mn steels is likely to be an over-estimate since it is known that some steel which is ordered to these specifications is not used for pressure vessels. The figure of 8,281 tons for proprietary steels should be noted and the figure of 6,726 tons for the low alloy steels. This tonnage divided between four producers is not very large, particularly in view of the large amount of technical work and data collection which is involved. The figure of 445 tons mainly produced by a single manufacturer for the 9% Ni category shows that this is a very limited market. The figures also show that Maker No. 2 produced 9,385 tons out of the total of 15,452 tons of steel in the special categories. This, taken in conjunction with the fact that they can supply larger and thicker plate than the other producers, highlights their importance to the pressure vessel industry.

37. Collected figures for stainless steel have not been submitted, but the individual submission from a major maker shows that they supplied 2,500 tons of stainless plate to pressure vessel fabricators in 1966.

LIMITATIONS IN PLATE SUPPLY (*Question* 4)

38. In the questionnaire to fabricators (Part I) there were complaints about difficulties experienced with 9% Ni steel, high alloy steels, stainless clad plate and quenched and

tempered steel. There were also complaints about the difficulty in obtaining steels manufactured by specific processes, eg electricarc steelmaking and vacuum degassing. Finally, there were complaints about limitations in size, thickness and weight.

39. The steelmakers have provided fairly detailed answers to these complaints. They stress the small demand for some of these steels. In the case of 9% Ni steel, the demand is so infrequent that there might be special difficulties in meeting a sudden demand because nickel itself is in short supply. The demand for stainless clad steel only amounts to 2,000 tons against a manufacturing capacity of 5,000 tons. Quenched and tempered steel is readily available from two manufacturers who produced 11,500 tons in 1966. There was practically no use of this material by the pressure vessel industry.

40. Electric arc steel was available from two manufacturers but only 2,000 tons of plate was supplied. Considerably larger quantities could be supplied if necessary. Vacuum degassing is also available now, although this is a recent development. One manufacturer supplied 75,000 tons in 1966 and another will have capacity for 100,000 tons in 1968. It would appear that any requirements of the pressure vessel industry for vacuum degassed steel can be met.

41. With regard to weight and dimensions, it is clear that Maker No. 2 is in a better position than the other plate suppliers. They can supply a maximum plate weight of 20 tons 156" wide, whilst the other suppliers have a maximum of approximately 12 tons and 136" wide. They can also supply large thick plate in their proprietary steel.

STEEL DELIVERY (*Question 5*)

42. The original submissions (Appendix E) complained about long deliveries, particularly on special qualities. The detailed submissions in response to the questionnaires to fabricators (Part I) agreed that there had been an improvement but quoted deliveries of 8–16 weeks for special qualities compared with 2–6 weeks for standard grades. The steelmakers answering the question about delivery periods suggested 2–6 weeks for standard grades with the simple C and C-Mn steels at the short end of this range, and fine-grained impact and high temperature tested steels at the long end of the range. Delivery periods (January 1968) for low alloy plate steel are 6–12 weeks, 3½% and 9% Ni steel 6–12 weeks, stainless steel 6–10 weeks and stainless clad steel 6–12 weeks. The manufacturers of proprietary plate steels indicate delivery periods of 4–10 weeks. Consequently, the two sides do not disagree very much in their estimates.

43. A major complaint from pressure vessel manufacturers was that replacements for defective plates added considerably to these delivery periods. The steelmakers acknowledge that this can add a further 4 weeks to the delivery periods.

STEEL DOCUMENTATION (*Question 6*)

44. There have been complaints that steelmakers are reluctant to accept special testing requirements and to provide the necessary documentation without lengthy delays. In general, the steelmakers claim that they are prepared to accept any requirements for special testing and documentation but concede that this might cause some delay.

STEEL CLEANLINESS (*Question* 7)

45. The frequent complaints about steel cleanliness were referred to the steelmakers, and they were asked for information on the comparison of cleanliness of steel plate produced in Britain, Japan and Germany. The steelmakers claimed that for equivalent processes and production conditions, corresponding compositions are much the same in degree of cleanness the world over. They claimed their information was that German and Japanese steelmakers had similar problems with laminations and inclusions. They mentioned that it was possible to improve the general standard of cleanness providing vacuum treatment is applied or times of production are extended and modifications to the process made. This inevitably increases basic costs over those that apply to the general standard level. The steelmakers do not accept that vacuum degassing and/or ultrasonic testing is undertaken by foreign steelmakers without some extra charge being made.

46. The steelmakers were asked to justify the 20% premium charged for ultrasonic testing. In reply they claimed that the extra cost of supplying the plate to ultrasonic standard resulted from modifications to the production procedures and reduced yield of material; from extra handling costs and the provision of accommodation and equipment for carrying out testing; from disruption and delay to production lines; and from increased rejection risks.

CHEMICAL COMPOSITION (*Question* 8)

47. In submissions given in reply to the questionnaire to fabricators (Part I) no major points were made about chemical composition, although some associated points were raised. For instance, it was suggested that since existing Standards allowed a considerable variation in several elements, it would be helpful if a maximum carbon equivalent could be specified. The steelmakers have indicated that they would agree to this and have pointed out that the new draft structural steel standard includes maximum carbon equivalent values.

48. Following up one of the points raised by pressure vessel fabricators, the steelmakers were asked whether there was a need for more information to be published on the segregation in large ingots and the difference between product analysis and ladle analysis. The steelmakers stated that the general picture was covered by publications in the Iron and Steel Institute from 1930 onwards, but they agreed that there may be a case for publishing more information on the large ingots which have been in common use for the production of various heavy steel products during the last 10 years.

49. With regard to the S and P contents, there is a major difference between the Heavy Plate Manufacturers and alloy steel and forging manufacturers. The Heavy Plate Manufacturers say that they would accept either 0·04% max. or 0·35% max. for S and P respectively, although this would lead to increased cost because their production process would have to be modified. The alloy and special steel manufacturers who use electric arc steelmaking can meet these limits without difficulty.

STEEL PROPERTY DATA (*Question* 9)

50. The questions in this section related to specific omissions in the property data available. To some extent the answers are linked with those to Question 1 which dealt

with the revisions to steel standards. In general, the answer seems to be that where there are omissions in existing standards, that this is covered by current testing programmes and these aspects will be covered in revised standards.

51. The answer to the question on specifying minimum property levels confirms the steel industry viewpoint that these should be based on accurate property test data and that they should not be 'adjusted' merely to conform to some preconceived idea of what the minimum property should be.

52. With regard to the question of type-testing, it should be noted that the Heavy Plate Manufacturers are currently discussing a comprehensive test programme with representative consumer organisations.

ANNEX A

Questionnaire (to fabricators) on materials for pressure vessels

1. *Rationalisation of steel*

It has been frquently reported to the Committee that rationalisation of steel specifications is desirable, but it is not clear whether these comments refer to the situation that has existed or whether these are complaints about the new specifications being issued, which are:

BS 1501	Steels for fired and unfired pressure vessels —plates
BS 1502	Steels for fired and unfired pressure vessels —bars and sections
BS 1503	Steels for fired and unfired pressure vessels —forgings
BS 3059	Steel boiler and superheater tubes
BS 3602	Steel pipes and tubes for pressure purposes —carbon steel
BS 3604	Steel pipes and tubes for pressure purposes —low and medium alloy steel
BS 3605	Steel pipes and tubes for pressure purposes —austenitic stainless steel

Included in this list are some specifications which have been published and some which are in draft form. Do these new specifications now provide the rational series that has been sought?

2. *Chemical compositions given in specifications*

(2.1) Some comments have been directed at particular aspects of composition, eg that the range of C and Mn in any one specification is too wide to allow general welding recommendations to be given. Have you any observations to make concerning general chemical composition ranges?

(2.2) A corollary of restricted composition ranges is that mechanical properties would vary more over a range of section sizes. Would this create difficulties in using such steels and, if so, which of the two alternatives is to be preferred?

(2.3) A particular aspect of composition concerns the S and P contents. Have you any views on the preferred levels of S and P for pressure vessel steel?

(2.4) Are other trace elements adequately specified?

3. *Steel availability*

(3.1) Some criticisms have been directed at the nonavailability or the availability only on extended delivery of specific types of steel, such as 9% Ni, stainless-clad plate, or quenched and tempered plate. It would help the Committee to have detailed information on these points, including details of steel types and any comparisons between British and foreign steel producers.

(3.2) There have also been comments concerning delivery delays on standard pressure vessel steels. It would be helpful to have any detailed information on this point and also to know whether these comments relate to all steel producers or to individual companies.

(3.3) One particular point that has been made is that there is not such a wide range of steel properties available in Britain as in Germany. Taking into account the British range of steels, from the standard BS 1501 steels to the proprietary Fortiweld and W30 steels, would you give your views on this?

(3.4) If you consider the British range of steels inadequate, can you identify the particular foreign steels or the particular property ranges which are not equalled by British steels?

(3.5) If you consider the British range of steels as excessive, how would you suggest the range available might be rationalised?

4. *Steel cleanliness*

(4.1) What is your experience of the standard of cleanliness of British pressure vessel steels supplied to you and how does this compare with steel of foreign manufacture?

(4.2) Do you specify ultrasonic examination for your plate supplies either by the steelmaker or by your own company? If so, do you have any difficulties with the interpretation of the results of ultrasonic examination?

5. *Non-standard steels and special features*

A comment has been made that British steelmakers are reluctant to accept orders to foreign specifications, eg DIN, and if they do accept such orders they charge a heavy premium for non-standard compositions. Another point made is that a heavy premium is also charged for extra features such as an impact test where this may not be provided in the specification, or for ultrasonic examination. Have you any detailed information on these aspects of steel supplies?

6. *Steel property data*

It has been mentioned that there is a lack of reliable property data on standard pressure vessel steels particularly for temperatures below the creep range. It has been said that there was a very large amount of high temperature property data published at the 1966 Eastbourne Conference by the British Steelmakers Creep Committee. Do you have any views on this topic; and if you feel that there are gaps in the information can you identify these?

7. *Specification of minimum property levels*

There is criticism of the low minimum level of properties of British standard steels in comparison with similar German steels. It is pointed out that this arises from the greater availability of accurate test data in this country, which in turn should allow lower safety factors to be used. Alternatively, it would be possible for different minimum properties to be specified for different confidence limits. Do you have any views on this point and how would you prefer to see properties specified?

8. *Other aspects*

You might feel that major problems exist concerning materials for use in pressure vessels in aspects other than those queried in sections 1 to 7 above, in which case your comments on these other aspects would be welcome.

ANNEX B

Questionnaire (to steel suppliers) on steels for pressure vessels

1. *British Standards*

It is generally agreed that there has been a big step forward with the issue of the BS 1501: 1964 standards for plates. These apply only to C and C-Mn steels, however, and there is concern about the delay in issuing the standards for other steels, such as proprietary steels, low temperature steels, low alloy steels and stainless steels. The Committee has noted that ISE/62/1 is responsible for these standards and that it was formed in 1961 to co-ordinate the work on plates. In view of this, it is difficult to understand why this committee only began to consider low alloy steels (eg 1% Cr ½% Mo, 2¼% Cr 1% Mo) in 1966 and austenitic stainless steels in 1967.

Can you comment on the reason for delay in issuing the:

Question (1.1) BS 1501 standards for the low temperature 3½% Ni and 9% Ni steels?

Question (1.2) BS 1501 standards for proprietary steels such as W 30 and Fortiweld?

Question (1.3) BS 1501 standards for low alloy steels such as 1% Cr ½% Mo, 2¼% Cr 1% Mo?

Question (1.4) BS 1501 standards for austenitic stainless steels?

It would appear that there has been more progress on plate standards than for other components. In particular, reference has been made to BS 1502 for bars and sections and BS 1503 for forgings. In relation to this latter it is noted that the committee responsible is ISE/62/2 but it is not clear why there has been so little progress during a 6 year period.

Question (1.5) Can you comment on the reasons for delay in issuing the BS 1502 and BS 1503?

There has been less comment about standards for pipes and tubes, presumably because there have been revisions for BS 3601–4 published containing high temperature properties. However, specific comment has been directed at the need for a revision of BS 3605 and also for the issue of the revision of BS 3059.

Question (1.6) Can you comment on the reasons for delay in issuing the revision of BS 3605 and BS 3059?

It is appreciated that there are many different interests concerned in the revision of a BS but the Committee of Enquiry would be interested to know how this question is seen from the point of view of the steelmaker. The standards are listed separately because individual steelmakers may be concerned only with certain steels. However, there is the broad question of British Standards procedure on which you may wish to comment generally and make suggestions for ways in which this procedure could be improved.

Question (1.9) Have you any general comments to make about British Standards procedure for materials standards or any suggestions to put forward for improving this procedure?

2. *Range of steels available*

There have been some complaints that the range of steels from British steelmakers is not as comprehensive as in some foreign countries, particularly Germany. In particular, it is said that a reasonable range can only be found in Britain by resorting to proprietary steels, which may be difficult to obtain. It is suggested that the complete range should be covered by British Standards and the steels should be available from all manufacturers. Further, it is said that since the British range of steels is not adequate, it would be helpful if foreign specifications could be purchased from British steelmakers. However, it is said that steelmakers are reluctant to accept such orders and that there is either a lengthy delivery or high premium charged.

Question (2.1) Do you consider the range of British steels to be adequate and equal to that available in any foreign country?

Question (2.2) Is it correct to say that this range necessitates the use of proprietary steels?

Question (2.3) Would you like to comment on the suggestion that it is desirable for the proprietary steels to be replaced by national standards?

Question (2.4) What is the position with regard to the supply of foreign specifications? Do you accept such orders? If so, what extra premium or extra delivery time would this involve?

3. *Steel supply*

The Committee of Enquiry would be interested to know which are the steelmakers mainly concerned with supply of steel to the pressure vessel industry. Consequently, it would be of assistance if the figures for tonnage supplied in 1966 could be disclosed. It is realised that this information may be difficult to provide since steel orders are not necessarily identified as to application, and the specification supplied may not be sufficiently informative. The types of steel in which the Committee of Enquiry are mainly interested are:

C and C-Mn steels;

Low temperature steels including 3½% Ni and 9% Ni;

Proprietary steels such as W 30 and Fortiweld;

Low alloy steels, eg ½% Mo, 1% Cr ½% Mo, 2¼% Cr 1% Mo;

Austenitic stainless steels.

The Committee of Enquiry is mainly interested in the supply of steel plate and consequently the relevant steel specifications are those included in BS 1501, or which will shortly be included in this standard.

Question (3) Can you provide figures for the tonnage of plate supplied to the pressure vessel industry during 1966?

4. *Limitations in plate supply*

Some of the submissions from pressure vessel manufacturers refer to limitations in plate supply affecting steel type, quality, or dimensions. In the following questions please indicate annual tonnage, range of qualities and maximum sizes.

Question (4.1) Do you supply plate steels manufactured by electric arc steelmaking?

Question (4.2) Do you supply plate steel which is manufactured using vacuum degassing? What, if any, premium is charged for this process?

Question (4.3) Do you supply quenched and tempered plate?

Question (4.4) Do you supply stainless clad plate?

Question (4.5) What is the maximum weight of plate supplied?

Question (4.6) What is the maximum width of plate supplied?

5. *Steel delivery*

There have been many complaints about long deliveries of plate steels used for pressure vessels. It is agreed that the delivery position on standard C and C-Mn steels has improved considerably as the general level of trade has fallen off in recent months, but it is feared that deliveries will lengthen again when activity increases. A particular point has been made about lengthy delivery of plates to replace those found to be defective during fabrication. There are strong complaints about the longer deliveries experienced on proprietary steels, which it is claimed are necessary to form a comprehensive range of steels. Finally, it is said that the delivery position is still very bad for special steels such as 9% Ni or special products such as stainless clad plate.

What is the current delivery position on the following:

Question (5.1) Standard C and C-Mn plate steels? (Where this varies with size, grade or thickness please give separate answers);

Question (5.2) Replacement plates?

Question (5.3) Proprietary plate steels? (Where this varies with size, grade or thickness please give separate answers);

Question (5.4) 3½% Ni or 9% Ni steel plate?

Question (5.5) Low alloy steel plate such as 1% Cr ½% Mo, 2¼% Cr 1% Mo?

Question (5.6) Austenitic stainless steel plate?

Question (5.7) Stainless clad plate?

Question (5.8) If the delivery position is worse for proprietary steels than standard steels, how may this be justified in view of the important position that these steels occupy in the range of steels available to the pressure vessel manufacturer?

Question (5.9) In what grades, sizes and quantities do you carry 'ready-to-use' stock or a 'part-processed' stock?

6. *Steel documentation*

There are complaints that British steelmakers are reluctant to accept special testing requirements for foreign, particularly East European, customers and to provide the necessary documentation without lengthy delays.

Question (6) Would you comment on the question of special testing requirements and documentation for foreign clients of pressure vessel manufacturers?

7. *Steel cleanliness*

The most frequent criticisms in the submissions from pressure vessel manufacturers concern cleanliness and the question of ultrasonic testing. It is suggested that the 20% premium for ultrasonic testing is exorbitant and that no pressure vessel manufacturer can pay this and remain competitive. Further, it is claimed that protected by this high premium, the steel industry has been slow to improve their general level of cleanliness, which is reported to compare unfavourably with foreign suppliers. It has been noted that several years ago the Japanese industry used electric arc steelmaking for pressure vessel plates and then adopted vacuum degassing. Vacuum degassing has also been applied more quickly in Germany than in Britain. In both countries vacuum degassed and ultrasonically tested plate is stated to be supplied without a premium being charged.

Question (7.1) How does the cleanliness of your pressure vessel steel plates compare with that available in Japan or Germany?

Question (7.2) Can you provide commercial or technical justification for the 20% premium charged for ultrasonic testing?

8. *Chemical composition*

C & Mn. In some submissions from pressure vessel manufacturers, it is suggested that the permitted range of C and Mn in specifications is too wide to allow satisfactory welding procedures to be specified. It is stated that there is insufficient information published by steelmakers on the segregation which is likely to be encountered in large ingots and hence the difference in product analysis (particularly in thick sections) from the ladle analysis of the steel. It is said that manufacturers' catalogues contain little useful information on this point and that standards committees do not have sufficient information to decide this point. It has also been mentioned that there is inadequate information published on the variation of composition within a specification range according to the section size. Because of this, it is suggested that a maximum carbon equivalent should be included in standard specifications, partly associated with individual product analyses for thick sections etc., which would give users some assurance about weldability.

S & P. There is some criticism about the maximum levels of these elements allowed in specifications since these are higher than in foreign specifications and higher than seem necessary for current steelmaking practice. There is some pressure for the maximum to be reduced from 0·5% to 0·4% or 0·35%. Further, in the case of S it is suggested that there should be a minimum value of 0·015% to avoid susceptibility to hydrogen cracking.

Question (8.1) What is your view on the inclusion of a maximum carbon equivalent in steel standard specifications?

Question (8.2) Do you agree that there should be more information published on the segregation in large ingots and the difference between product analysis and ladle analysis?

Question (8.3) Would you please comment on the proposal for individual product analysis coupled possibly with more tolerant composition limits?

Question (8.4) Do you agree that there should be more information published on the variation of analysis within the specification range according to the section size? Is such information available; if not, what would be required to obtain it?

Question (8.5) It is suggested that the range for S and P for pressure vessel steel specifications should be:

$$\begin{array}{lcl} P = 0{\cdot}04\%\ \text{max.} & & P = 0{\cdot}035\%\ \text{max.} \\ & \text{or} & \\ S = 0{\cdot}015/0{\cdot}04\% & & S = 0{\cdot}015/0{\cdot}035\%\ \text{max} \end{array}$$

What is your reaction to these suggestions?

9. *Steel property data*

There is widespread approval of the efforts of steelmakers in providing elevated temperature property data and as conveniently summarised at the BISRA/ISI Eastbourne Conference. There are specific comments about gaps in this data, eg proof stress data in the range 50–250°C, low alloy steels, austenitic stainless steels, and specific component forms such as very thick plates or large forgings. There seems to be a lengthy delay between property collection by the BSCC and the use of this data in material or design standards. In particular, it was mentioned that the discussions relating to BS 1515 Part II have been seriously handicapped by the lack of property data on austenitic steels. Some submissions also refer to the difficulties encountered in defining minimum property levels to be used in standards to ensure that pressure vessel manufacturers are not placed at a disadvantage compared to foreign manufacturers.

Have you any comment to make on the availability of:

Question (9.1) proof stress data in the temperature range 50–250°C?

Question (9.2) elevated temperature properties of low alloy steels of the Mo and Cr/Mo types?

Question (9.3) elevated temperature properties of austenitic stainless steels including the Hi-proof steels?

Question (9.4) elevated temperature properties on very thick plates and large forgings?

Question (9.5) large scale fracture data (so-called 'type test' data), and low cycle fatigue data on pressure vessel steels in the relevant range of qualities, conditions, and sizes?

Question (9.6) Have you any comment to make about the controversy concerning the specification of minimum property levels?

APPENDIX M

Surveys on welding consumables: summary report

1. One of the major topics considered by the Committee of Enquiry was the question of materials of construction; during these discussions the subjects of welding consumables and their supply were raised. It was considered necessary to have questionnaires on similar lines to the materials questionnaires (See Appendix L) which would be circulated to major consumable manufacturers and also to a number of leading fabricators in the pressure vessel industry.

2. Attached at Annex A is the questionnaire sent to 12 welding consumable manufacturers (replies were received from 8) and to 12 fabricators (replies were received from 10). The questionnaire is divided into two parts:

Part I—is concerned with specific consumables, the high and low temperature properties of those consumables, and the range of electrodes and delivery situation as at February 1968;

Part II—is concerned with the development of consumables and the relationships between consumable manufacturers and the steelmaking and fabricating sections of industry.

A summary of the views expressed in the replies is given in the ensuing paragraphs.

Electrode availability

3. From the answers given by electrode manufacturers, it appeared that the majority provided a range of electrodes covering both manual electrodes and automatic consumables. In answering the question whether their range was as good as in any other country, most claimed that the range of manual electrodes was adequate but they agreed that the range of automatic consumables was incomplete and could be improved.

4. The welding fabricators agreed with these comments but gave more detail. With regard to manual electrodes, it was mentioned that the availability was satisfactory for plain carbon and simple steels but less satisfactory for special steels. In order to get a comprehensive range, it was necessary to use electrodes from foreign manufacturers or British associates of foreign companies. With regard to automatic consumables, it was stated that the choice was limited and that it was necessary to rely on imported materials to obtain a satisfactory range.

Delivery situation

5. The welding electrode manufacturers claimed that the delivery position was satisfactory for the main types of electrode covered in the survey. They agreed that there might he lengthy deliveries for certain consumables for automatic and semi-automatic processes, but they stressed that the demand for these specialised materials was small and that they had difficulties in obtaining alloying metals like nickel or the special core wires they needed.

6. The welding fabricators confirmed these points, agreeing that standard materials were readily available but that special materials, eg proprietary compositions, low alloy creep resisting steels, Ni steels and stainless steels, could have delivery periods ranging from three weeks to two months.

High temperature property data

7. The electrode manufacturers conceded that high temperature property data on their products was 'limited', 'incomplete' or 'not available'.

8. The welding fabricators suggested that the high temperature property data available from electrode manufacturers was virtually nil and that where knowledge of this was necessary, they had to carry out the testing in their own laboratories.

Collaborative testing work

9. All the electrode manufacturers stated that they had no collaborative work with other electrode manufacturers to provide property data on welding consumables, and most went on to say that they would not support any proposal for collaborative testing. They also stated that there was practically no collaborative work with steelmakers or fabricators on the properties of welded joints; there was some willingness to collaborate if such a programme could be arranged.

10. The welding fabricators confirmed that there are no general arrangements for collaborative work, although there might be some limited private arrangements between individual companies. Generally, the fabricators indicated a willingness to join any collaborative testing programme which might be arranged.

Low temperature property data

11. Some of the electrode manufacturers claimed that adequate low temperature property data were available, mainly in the form of Charpy V notch tests. They indicated that there was no collaborative work by electrode manufacturers to obtain this information, and that generally they would not co-operate in any test programme.

12. The welding fabricators suggested that the information provided by electrode manufacturers was 'sketchy', 'vague' or 'incomplete'. They found it necessary to supplement this information by extensive testing in their own laboratories. They confirmed that there was no collaborative work in progress to determine low temperature property data on welded joints, but generally indicated a willingness to co-operate if such a programme was arranged.

Development of consumables and equipment

13. The electrode manufacturers stated that they were rarely consulted at an early stage of steel development, so that they could have a chance to develop matching electrodes. They said that their main problems were with regard to automatic consumables and in obtaining small quantities of special wires needed for their development work. The main future developments were seen in the field of automatic processes.

14. The welding fabricators generally appreciated the difficulties faced by electrode manufacturers in meeting widely different demands from individual fabricators without any agreed standards for the properties required. There was the suggestion that one function of a 'Pressure Vessel Authority' would be to provide a forum for the joint discussion of these matters leading to agreed standards.

Certification of electrodes

15. The electrode manufacturers expressed general satisfaction with the present methods for assessing electrodes, wires and fluxes. The welding fabricators were not so satisfied, suggesting that insufficient information was given which might not always be accurate. Further, the information was restricted to downhand welding, whereas information on the vertical position should also be given. There was also the suggestion that necessary information was withheld under the guise of 'trade know-how'.

ANNEX A

Questionnaire (for welding fabricators/consumables manufacturers) on pressure vessel welding consumables

PART I

1. *Availability*

Do you manufacture/utilise consumables for welding the following steel types?

Question (1.1) Carbon-manganese steels, eg BS 1501: 151, 161, 211, 213, 221, 224.

Question (1.2) Proprietary steels, eg W 30, Fortiweld.

Question (1.3) Low alloy creep resisting steels, eg 1% Cr ½% Mn, 2¼% Cr 1% Mo.

Question (1.4) Low temperature steels, eg 3½% Ni, 9% Ni.

Question (1.5) Austenitic stainless steels, eg Types 304, 316, 347, 321.

Question (1.6) High proof stress stainless steels.

2. *Range of electrodes available*

Question (2) Do you consider that the range of welding consumables available to the pressure vessel industry is adequate and equal to that in any foreign country?

3. *Delivery situation*

Question (3.1) What is the delivery position with regard to welding consumables?

Question (3.2) If the delivery position varies with electrode type, what is the delivery position for electrodes for each of the steel types listed in Question 1?

4. *High temperature property data*

There have been frequent comments upon the lack of mechanical property data at elevated temperatures on weld metal and welded joints.

Question (4.1) What is the extent of the elevated temperature property data available for electrode materials/weld metals for the materials listed in Question 1?

Note: Questions (4.2) and (4.3) for welding consumables manufacturers only

The steelmakers have had a collaborative organisation to co-ordinate testing of steels. There is interest in the position with regard to welding consumables.

Question (4.2) Is there any collaborative arrangement amongst welding electrode manufacturers for the collection of high temperature property data on welding consumables?

Question (4.3) If the answer to question (4.2) is 'No', would you support a proposal for collaborative testing?

Apart from the properties of plate material and of weld material, there is interest in the properties of welded joints. Clearly, this is not the individual responsibility of a steelmaker only or a welding electrode manufacturer only, but the Committee of Enquiry would like to know whether any arrangements have been made for collaborative testing between the respective interests.

Question (4.4) Is there any collaborative test programme between steelmakers, electrode manufacturers and plant fabricators on the properties of welded joints?

Question (4.5) If the answer to Question (4.4) is 'No', would you be prepared to join in collaborative work of this type?

5. *Low temperature property data*

For many pressure vessel applications, good low temperature toughness is required and there is interest in the availability of low temperature property data on weld metal and welded joints.

Question (5.1) What low temperature property data is available for the welding consumables which you make for/use in the pressure vessel industry?

Note: Questions (5.2) and (5.3) for welding consumables manufacturers only

Question (5.2) Is there any collaborative work between electrode manufacturers for the collection of low temperature property data?

Question (5.3) If the answer to Question (5.2) is 'No', would you be prepared to co-operate in collaborative testing of this type?

Question (5.4) Is there any collaborative work between steelmakers, welding electrode manufacturers and plant fabricators on low temperature properties of welded joints?

Question (5.5) If the answer to Question (5.4) is 'No', would you be prepared to join in collaborative work of this type?

PART II (*For welding consumables manufacturers only*)

Question (6) To what extent and at what stage are you consulted during the development of materials (for fabrication by welding) by steelmakers and other bodies?

Question (7) What factors govern the development of new welding consumables within your company, and to what extent do you develop consumables to meet particular industry or customer requirements?

Question (8) Do you develop and market welding machine equipment in addition to welding consumables? In the light of the present situation and current developments in what way do you see the fabrication methods developing, bearing in mind international competition?

Question (9) Is the development of automatic equipment geared to the requirements of the fabricating industry and what methods do you use to ensure that such developments are in accord with the industry's needs?

Question (10) Do you consider that the present method of certifying electrodes, wires and fluxes accurately reflects the problems of production welding? If the answer is 'No', please indicate how in your opinion this could be modified.

Question (11) Are there any other matters of importance connected with welding consumables you consider this Committee should be aware of?

PART II (*For welding fabricators only*)

Question (6) Do you consider that sufficient attention is given to the development of consumables during the development of materials for pressure vessels? If the answer is 'No', could you indicate *briefly* how this could best be done?

Question (7) Please indicate what approximate annual tonnage of pressure vessels fabricated by your company are (a) manually welded and (b) semi-automatic or automatically welded. In the light of the present situation and current developments, in what way do you see fabrication methods developing, bearing in mind international competition?

Question (8) In your opinion do you consider that the development of automatic equipment is geared to the needs of the fabricating industry? If not, please indicate how you think this situation could be rationalised.

Question (9) Do you consider that the present method of certifying electrodes, wires and fluxes accurately reflects the problems of production welding? If the answer is 'No', please indicate how in your opinion this could best be modified.

Question (10) Are there any other matters of importance connected with welding consumables you consider this Committee should be aware of?

APPENDIX N

Survey of R & D in the pressure vessel industry: summary report

Prepared for the

Committee of Enquiry on Pressure Vessels

(May 1968)

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Preface

A survey of research and development in the pressure vessel industry was made by staff of the UKAEA Reactor Materials Laboratory at the request of the Committee of Enquiry on Pressure Vessels. The survey was based on replies received to two questionnaires sent out in 1967 to UK organisations connected with the pressure vessel industry. Two detailed reports analysing these replies have been submitted to the Committee; the present document is an edited version of these two reports. References to individual organisations have been omitted and all views remain anonymous to respect the confidential nature of the replies.

Abstract

A survey, based on the information obtained from questionnaires completed by 268 organisations, has been made on R & D relevant to the pressure vessel industry. The survey covered the activities of 129 organisations over the period 1962–71. Over 400 qualified staff were found to be employed on R & D corresponding to an annual expenditure of the order of £3½M; an increase of at least 10% is expected over the next five years. The work covers a wide spectrum of activities but much of it is devoted to work directly connected with procedure trials for current contracts.

The proportion of the total R & D which is contributed by each type of organisation has been estimated; pressure vessel manufacturers, as a group, produce the greatest single effort and, when taken together with materials manufacturers, contributed half the overall effort on R & D. It was found that 17 organisations, each having over 10 men engaged on R & D work, produced at least 40% of the national effort on pressure vessel R & D, the remaining 60% being contributed by the remaining 300 or so organisations.

R & D associated with design aspects of vessels takes up more effort than any other single topic but is closely followed, in terms of effort applied, by data determination on materials and the development of materials. Generally the effort applied to a given subject by different types of organisation is in the same ratio as their contribution to all R & D ie pressure vessel manufacturers produce the largest single contribution. Materials manufacturers are however more prominent in both material development and property determinations. Even in these subjects pressure vessel manufacturers are more active in specific areas notably the development of weld metals and the assessment of weldments.

The ratio of laboratory investigations to works on production studies varies between subjects. Work on design aspects of pressure vessels has similar amounts of effort on theoretical studies, laboratory tests and tests on models or components; in materials development the effort devoted to laboratory investigations is about twice that devoted to prototype or production studies. The amount of effort applied to development of existing techniques is generally identical to that applied to development of new techniques. This equivalence exists with welding processes, quality control, techniques for manufacture of pressure vessels and of components.

Quoted examples of R & D over the past 5 years show that pressure vessel manufacturers work largely towards the improvement of fabrication and inspection techniques, the avoidance of difficulties, and the maintenance of a commercial advantage. This results in a comparatively small amount of the work being published and in a duplication of effort. Materials manufacturers concentrate on development of products, involving a large amount of data collection, and the results are published more widely. Public corporations and government financed organisations tend to have a greater proportion of research directed towards basic understanding of failure mechanisms and design approaches; publication of their work is usual.

The respondents considered that much of the information from R & D work had been applied, but had difficulty in quoting specific examples. In many cases, application meant that trouble shooting had been successful, that new processes or new materials had been successfully adopted and that an organisation had been able to keep up with or ahead of its competitors. For these reasons the financial gains resulting from R & D could rarely be obtained and few organisations appear to have information from which the cost effectiveness of R & D could be obtained. The application of R & D obtained by other organisations does not appear to be common although several companies acknowledge assistance from BWRA (now the Welding Institute).

Areas (suggested by the industry) where more R & D is needed over the period 1967–71 are broadly in line with their reports of the work proposed. However more emphasis is placed on larger scale work involving the understanding of the significance of defects, assessment of behaviour of weldments and rationalisation of design and design standards. These are recognised as problems beyond the capabilities of most individual organisations. From the information received it is clear that the different parts of the industry do not appear to appreciate the requirements of one another.

The above led to the suggestion of the need for an organisation capable of tackling these problems; this is recognised by the majority of organisations who favoured the setting up of a body similar to that of the PVRC in the USA. In the majority view such an organisation would also have similar functions to the PVRC, it would be financed by government and industry, and it would be closely integrated with organisations responsible for preparation of standards.

CHAPTER 1

Introduction

1. The replies received to the first questionnaire covered the period 1962–71. This has been broken down into the relative contributions made by different types of organisations over different periods of time with approximate indications of the research effort applied to individual technical problems.

2. The first questionnaire consisted of two sections. The first section requested background information and whether or not R & D was undertaken. The second section consisted of eight principal questions on the type of work, each of these questions containing several sub-questions. All sub-questions covered a period of ten years and asked for division of work into 'past' (1962–6), 'present', 'immediate future (sanctioned)' and 'long term future'. An additional question asked for total qualified effort over two periods only (1962–6 and 1967–71), the effort being placed into one of the following categories (*a*) less than 10 man-years (*b*) 10–50 man-years and (*c*) greater than 50 man-years. In the following analysis these categories have been described as low, intermediate and high effort levels.

3. In analysing the questionnaires some adjustments had to be made to the replies to achieve consistency. Some replies were rejected as being beyond the scope of the survey. A pressure vessel was defined as one built to a specific design standard along with connecting flanges, pipework etc; concrete pressure vessels, gas cylinders and pipes were excluded. Each organisation replying has been classified under one of several headings as to 'type of establishment'. Several organisations could legitimately lay claim to work under a number of these headings but to simplify the analysis it was decided to allocate each organisation to one heading only; this corresponded to what was regarded as the main activity of that organisation. This decision has avoided problems of duplication but has meant that some types of establishment are apparently under represented. Only one trade association was found doing R & D, and reference to the work that this association is doing has been included under the heading of Research Association.

4. The form of questionnaire was such that primary information could be extracte from it in three ways: (*a*) the numbers and types of organisation working on a give research topic; (*b*) an estimate of the *overall* effort on R & D for each of the periods 1962–6 and (*c*) an approximate estimate of the contribution by each type of organisation to the overall effort. The amount of effort devoted to each subject (or topic forming part of that subject) could not be obtained directly, so two types of calculation (effort weighting and effort index) have been evolved. The derivation of effort weighting methods is given in Annex II.

5. Further information on R & D relating to pressure vessels was obtained from a second questionnaire (see Annex A) sent out to those organisations employing intermediate and high effort levels (10–50 man-years, and greater than 50 man-years, over the period 1962–7). Information was obtained on four main topics:

(a) A description of the main areas of R & D (with effort, or costs and publications) over the past five years;

(b) Details of application of the results of R & D including changes brought about, financial savings or quality improvements;

(c) Suggestions about the main fields in which R & D should be undertaken in the next five years;

(d) Opinions on whether UK industry would benefit from the formation of an organisation similar to the Pressure Vessel Research Committee (PVRC) of the USA.

6. The information presented in subsequent sections is based almost exclusively on the completed questionnaires. The first questionnaire enables a broad outline to be obtained of pressure vessel R & D undertaken by 129 organisations. A similar number of organisations connected with the industry were not doing any research or development, see Table N(1). The more detailed aspects apply to about 40 of the larger organisations which, between them, are responsible for about 45% of all pressure vessel research and development.

TABLE N(1)

Summary of returned questionnaires of the R & D position as at May, 1968

	University departments	Government departments	Public corporations	Research associations	Manufacturers of materials and consumables	Manufacturers of equipment	Manufacturers of pressure vessels	Inspection organisations	Industrial users of pressure vessels	Consultants	Trade associations and kindred organisations	TOTALS
Doing R & D	41	4	11	5	26	2	26	2	9	3	—	129
Completed section I (not doing R & D)	45	4	5	2	65						2	123
Others (no reply, rejections, etc.)	23	1	5	—	55						13	97
TOTALS	109	9	21	7	188						15	349

CHAPTER 2

Overall distribution of R & D

7. The numbers (effort levels) of qualified staff concerned with R & D in each type of organisation are shown in Table N(2). The decrease from 129 active organisations in 1962–6 to 107 organisations making a forecast for 1967–71 probably reflects uncertainty in some university research programmes and the tendency for low effort organisations to avoid forecasts. The changes between past and predicted effort levels are shown schematically in Fig. N(1). Twenty of the low effort level and 2 of the intermediate level did not make any prediction of effort for 1967–71. Seventeen organisations in the low effort level category expected to increase R & D to intermediate effort level. Eight of these are universities and CAT departments; the remainder of the increases are spread uniformly over other kinds of organisations. At the intermediate effort level 2 organisations expected to increase and 2 expected to decrease effort. The only general conclusion is that the higher the existing effort level the greater the stability with regard to the future.

8. The total numbers in each type of organisation is illustrated in Fig. N(2). Universities exceed other categories, with pressure vessel and materials manufacturers giving the next highest levels. The small number (2) of manufacturers of pressure vessel equipment is misleading. Fourteen organisations including many large establishments manufactured pressure vessel equipment as a subsidiary activity but are classified in this analysis according to their main interest (para 3). Manufacture of equipment for pressure vessels appears to be a subsidiary rather than a main activity.

9. Indication of proportions of the total R & D due to each type of organisation is possible using effort weighting (Annex B). On this basis the relative proportions of R & D change significantly (Figs. N(3 & 4)) from those shown by analysis of numbers of organisations (Fig. N(2)). Pressure vessel manufacturers produce the greatest amount of R & D, the manufacturers of materials the next largest and universities fall back to third place. Table N(3) summarises the relative output in terms of percentage of total R & D.

10. This 'league table' order of the different types of organisations does not change between the two periods of time. However the total R & D effort forecast for 1967–71 is 2,330 man-years compared with 2,130 man-years for 1962–6. Most types of organisation show a small percentage decrease for the future in contrast with the higher expected output of the universities. The absolute (as opposed to percentage) efforts are however either constant or increasing. The significant increase expected in the output of the universities may be over-estimated; it is caused by eight departments anticipating an increase in their effort level from low to intermediate. The effort weighting adopted in the calculations increases from 5 to 25 and this fivefold increase is probably in excess of that likely to occur quickly even in an expanding university department. A list of SRC research grants current in the pressure vessel field in 1967 is given in Annex E.

TABLE N(2)

Categories of organisation in terms of effort level

	1962–66				1967–71			
	Low effort level <10 man-yrs.	Intermediate effort level 10–50 man-yrs.	High effort level >50 man-yrs.	TOTAL	Low effort level <10 man-yrs.	Intermediate effort level 10–50 man-yrs.	High effort level >50 man-yrs.	TOTAL
Universities etc.	34	7	—	41	19	15	—	34
Government departments	1	2	1	4	1	2	1	4
Public corporations	4	5	2	11	2	6	2	10
Research associations	2	3	—	5	1	4	—	5
Manufacturers of materials	14	8	4	26	5	8	5	18
Manufacturers of PV equipment	1	1	—	2	1	—	—	1
Manufacturers of PV's	11	7	8	26	6	8	9	23
Inspection organisations	—	1	1	2	—	1	1	2
Industrial users of PV's	6	2	1	9	3	3	1	7
Consultants	3	—	—	3	3	—	—	3
	76	36	17	129	41	47	19	107

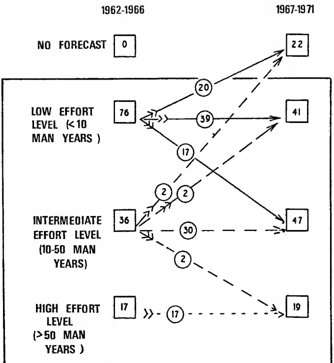
1962-1966
1967-1971
NO FORECAST
0
22
LOW EFFORT LEVEL (<10 MAN YEARS)
76
41
20
39
17
INTERMEDIATE EFFORT LEVEL (10-50 MAN YEARS)
36
47
2
2
30
2
HIGH EFFORT LEVEL (>50 MAN YEARS)
17
19
17
TOTAL EXCLUDING NO FORECAST
129
107

FIG. N(1). How organisations expect their effort level in 1967–71 to compare with 1962–1966

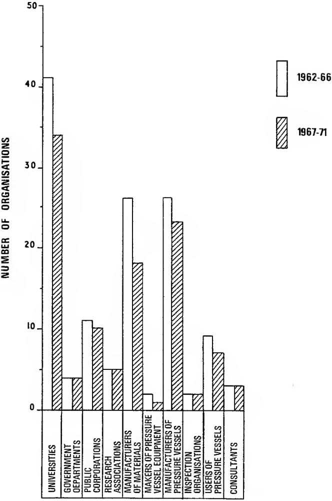

FIG. N(2). Total numbers within each type of organisation

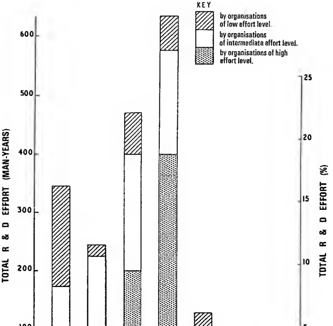

FIG. N(3). Total amount of R & D effort (1962–1966) by each type of organisation

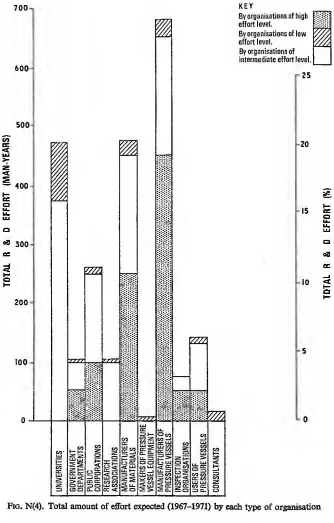

FIG. N(4). Total amount of effort expected (1967–1971) by each type of organisation

TABLE N(3)

Contribution of types of organisations as percentage of total effort

	1962–66	1967–71
Manufacturers of pressure vessels	29·5%	29·3%
Manufacturers of materials	22·0	20·3
Universities etc.	16·2	20·3
Public corporations	11·5	11·3
Industrial users of pressure vessels	6·1	6·0
Government departments	4·9	4·5
Research associations	4·0	4·5
Inspection organisations	3·7	3·2
Manufacturers of PV equipment	1·4	0·2
Consultants	0·7	0·6
	100%	100%

11. The increase of overall effort in the future occurs despite the fact that only 107 organisations forecast future effort compared with 129 currently active. Since the majority of those organisations not making a forecast were from the low effort level group the effort predicted for 1967–71 is likely to be underestimated by only a small amount. It is reasonable to conclude that planned effort on pressure vessel R & D will be at least 10% higher in 1967–71 than that expended in the period 1962–6.

12 The contribution to R & D by the different effort levels is shown in Figs. N(3) and (4). A high proportion of R & D output by the pressure vessel manufacturers is contributed by the high effort level organisations. In 1962–6, 8 establishments produced 19% of all R & D and, in 1967–71, 9 establishments are expected to produce almost 20% of the total. Manufacturers of materials and Public corporations have a lower fraction of their total output contributed by high effort level establishments. Because of the method of effort weighting used (Annex B) these proportions of total effort by high effort level organisations are probably conservative. Even so 17 organisations contribute 40% of the total pressure vessel R & D for both periods of time. The remainder of the R & D is shared between 112 organisations; if the 'no replies' and 'no R & D' replies to the questionnaire are all regarded as relevant to the industry and are included, then about 300 organisations can be regarded as carrying the remaining 60% of the total R & D.

CHAPTER 3

Relative distribution of R & D between subjects

13. A broad indication of the relative interest in the eight main subject areas on which information was sought in the first questionnaire can be obtained by taking the numbers of organisations working on any aspect (or sub-area) as illustrating interest in the subject as a whole. The relative popularity (Fig. N(5)) shows that R & D associated with design aspects attracts more organisations than any other subject and is followed closely by determination of data on materials. There is a gradual decrease in the number of organisations working on other subjects with the least number (15) of organisations working on techniques for manufacture of pressure vessels. This numerical analysis of R & D is shown, later in the present appendix, to give a good quantitative description of the relative intensity of R & D between different subjects.

14. R & D on a given topic was requested with respect to four timescales—'Past (since 1962)', 'Present', 'Immediate Future (sanctioned)' and 'Long Term Future'. The trend of popularity with respect to time is shown in Fig. N(5). The greatest number of organisations are working at the present time, with a gradual fall off to 'Past' and 'Immediate Future' and a spectacular decrease for the 'Long Term Future'. Although the total number of organisations giving effort forecasts for 1967–71 decreased by 22, 16 of these did indicate in some sub-areas that R & D was planned for the future. The fall-off shown in Fig. N(5) in the number of organisations participating in R & D in each subject in the future, is greater than these overall numbers suggest; this inconsistency is probably due to lack of detailed planning. This tendency for the number of organisations to decrease as time becomes more remote appears, with few exceptions, for each sub-area and suggests that replies to the 'Present' are more accurate. In spite of the change in the number of organisations with time the relative popularity of the eight subjects is practically constant with time, the only significant relative decrease being R & D into techniques for manufacturing components.

15. A more detailed picture of the relative effort applied to each problem is obtained by estimating the effort applied using effort index (Annex B). The effort index applied to each topic is given in Annex C which includes a short discussion on the variations to be expected over the period 1967–71 and on relative contributions of each type of organisation to a topic. The overall pattern is broadly in line with that shown in Fig. N(5) and as further detailed in replies to the second questionnaire. The distribution of effort remains much the same over the period 1967–71. The only significant increase in effort forecast occurs with 'R & D Associated with Design Aspects' where stress analysis involving creep and plastic behaviour is increasing, and more effort is to be used on studies of failure criteria and the amount of laboratory testing. Significant decreases are expected for the development of 'other non-ferrous metals', techniques for assessing weldments, and elastic stress analysis.

16. Detailed descriptions of R & D show that there is considerable apparent duplication in the R & D undertaken by the pressure vessel manufacturers. They predominate in the development of welding processes and substantial proportions of the total R & D are devoted to electroslag welding developments (7 organisations), developments in non-destructive testing and particularly ultrasonics (5 organisations),

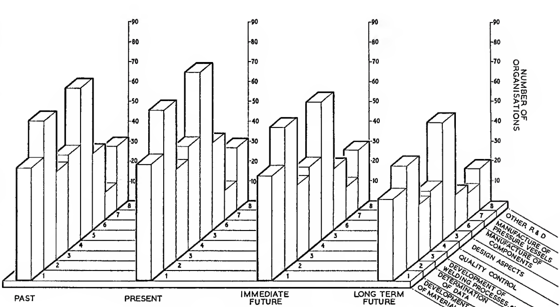

FIG. N(5). Numbers of organisations working in each area of R & D tube to tube plate joints using various techniques (4 organisations), and strip cladding of vessels. There is almost certainly considerably more duplication in several organisations not giving sufficient detail for comparison.

17. The duplication of work in many cases is probably because of the need to keep abreast of the field especially with technical know-how and to gain commercial advantage. The results of R & D are, with very few exceptions, restricted to internal reports with the probable intention of commercial exploitation. This lack of dissemination of information is understandable from the point of view of commercial advantage but further enquiry might be useful as to whether or not the gain is sufficiently long term to compensate for the replication of effort. Examples were received of what would have been unnecessary R & D if technical know-how were more widely disseminated.

18. The subjects of interest to materials manufacturers are principally development of steels, both as plate and forgings, improvements in steel quality and the determination of data for the products. The results appear as trade publications, sales literature, etc. and a significant proportion are fed into BSI for formulation of Standards. Publication is wider than in the pressure vessel industry and there is less apparent duplication of work. An exception occurs in the case of electrode manufacturers who tend not to publish.

19. With the remaining types of organisations there is a significant change in research topics. There is progressively less tendency to develop materials and know-how for their use, and research into failure mechanisms and design concepts becomes predominant. Coupled with this trend is a much increased number of publications in the open literature. About 70% of the quoted publications are from public corporations and government financed (partially or wholly) organisations. The majority of large scale testing (model or prototype tests) is done by these categories of organisation. This may well be a reflection on the cost of such tests and the low possibility of immediate commercial exploitation. Several organisations are carrying out theoretical and experimental design studies although the extent (from quoted costs) is low.

20. In summary it appears that R & D by pressure vessel manufacturers is largely directed towards fabrication and inspection techniques; the work is rarely published, entails considerable duplication with competitors and is to a large extent aimed at the avoidance of difficulties and maintenance of a commercial advantage. Much of the work is related to short-term problems and procedure trials for immediate contracts. Materials manufacturers concentrate on development of the product and collecting data and there is less restriction on publication. With public corporations and government financed organisations there is a greater proportion of the research directed towards basic understanding of failure mechanisms and design approaches, and publication of the work is usual.

CHAPTER 4

Costs of R & D

21. An approximation to the total cost of R & D can be obtained by taking the total averaged qualified effort values quoted in conjunction with an estimated cost of £8,000 per qualified man-year. On this basis the *annual* expenditure on R & D over the period 1962–6 has been of the order of £3·5M. The 10% increase in effort for the period 1967–71 (para 10) would be expected to raise the cost at least proportionately.

22. It does not appear likely that significantly more accurate cost figures can be obtained. Using a cost factor of £8,000 per man-year the organisations completing the second questionnaire would have entailed a total expenditure of about £8·4M compared with the total costs quoted of £4·6M. This discrepancy is due to a number of factors, the most important of which is the incomplete cost figures (and probably incomplete returns of all R & D) given in the second questionnaire.

23. The basis of costing R & D varies widely between organisations. Several organisations appear to be costing on the basis of £1,000–£2,000 per man-year. Although this may be due to incomplete returns of R & D it is probable that some organisations are costing on the basis of salaries only or salaries plus direct charges only. Overheads will vary considerably depending on the organisation and the type of R & D. CEGB Annual Report figures, for example, show that salaries are responsible for only about 40% of the total cost of R & D. These salary figures include support staff so that the true percentage in terms of 'qualified man' salaries will be lower and probably in the region of 20–25%. On this basis the assumed value of £8,000 per qualified man-year, which includes cost of supporting staff, direct charges and overheads, is probably of the right order for the majority of the industry; a lower figure almost certainly applies to university expenditure.

24. Mention should be made of the difficulty in costing pressure vessel R & D in industries with products not solely applicable to pressure vessels. The difficulty is most pronounced with materials manufacturers (particularly steelmakers and electrode manufacturers). This means that any assessment of R & D costs of the pressure vessel industry as a whole is based on judgement of apportionment of costs.

25. The annual estimated expenditure on R & D (effort at £8,000 per man-year) by those companies whose predominant interest is in manufacturing pressure vessels and chemical and engineering plant is of the order of £1M. This figure does not include companies which manufacture pressure vessels as a subsidiary activity. To this must be added the relevant R & D contributed by other organisations; an annual value of £2·5M can be estimated on the basis of effort. There is little evidence given in the second questionnaire to confirm this value. However, rough estimates may be obtained from Statistics of Science and Technology (HMSO 1967) where private industry spent £1·8M in 1964–5 on R & D relevant to 'Boiler and Boiler House Plant'; to this should be added some fraction of £10·5M on 'Iron and Steel' and some fraction of other topics. These fractions cannot be quantified but they indicate that the total of £3·5M per annum is a reasonable estimate.

26. The survey gave the strong indication that many organisations either do not have an accurate basis for costing R & D or, if they have, the costs are not readily available.

CHAPTER 5

Application of R & D

27. The evidence obtained shows that the majority of the R & D which is undertaken has been applied to changes in production procedures, specifications or designs. Pressure vessel manufacturers essentially apply R & D towards improving fabrication techniques; the comment of one large fabricator that R & D 'has resulted in either changes to our current welding or fabrication practice or to new procedures for materials and processes new to our company' provides a good summary of the replies from all pressure vessel manufacturers. The changes or new methods resulted in improved quality and in some cases better economy. In several instances the work has been done to permit the company to enter a new field involving the use of a new material. A point often made is that R & D can avoid considerable loss to the company.

28. The use of R & D to permit design and fabrication beyond normal design standard practice is mentioned by only two organisations and none of the intermediate or high effort level organisations quote the use of R & D specifically for this purpose.

29. The materials manufacturers report that their R & D is largely applied to improvement of quality and optimisation of material properties and, as an objective, towards the selling of the product. This has led to the 'production and marketing of a number of new steels' which is stated to be following the general policy of keeping 'one stage ahead of demand in every major application'. With other types of organisations there is a greater use of R & D to amend operational conditions and design philosophies against specific failure mechanisms with less emphasis on changes in techniques. Replies from universities in the intermediate effort level groups generally show little evidence of application. In contrast letters received from low effort level universities quote a number of examples of R & D used to modify and define designs of pressure vessels; most of these applications arise from work sponsored by industry.

30. Few examples are given of the application of R & D findings obtained from other organisations, although one commented that 'results (from other organisations) are applied in the same manner as results which have been obtained within our own research organisation' is probably true of several other establishments. The use of external R & D was quoted by only 8 organisations. Six of these, including four pressure vessel manufacturers, had made use of R & D (or advice resulting from it) from BWRA. Other organisations mentioned, each once only, were: NCRE, NEL, PERA and UKAEA Reactor Materials Laboratory. Only one organisation used PVRC publications extensively. Taking into accomt the views of organisations regarding the PVRC in the USA (paras 46–51) it appears that the work already published by PVRC is not only *not* fully utilised but is also *unknown* to many organisations.

31. Only one company made reference to advice and help received from industrial organisations. Acknowledgement was made to assistance from 'suppliers of welding electrodes', and the 'aluminium industry—considerable assistance when requested'. On the debit side the same company had 'received from them (the steel industry)

comparatively little information, with the exception of (one named steelmaker)'. In contrast the comments of two steelmakers are: 'The barrier to the application of the research work does not therefore lie in the attitudes of the production branches, but in the attitudes of the steel users'; and '. . . . our R & D has to be 'customer end-use' oriented. Therefore when a steel of ours is destined for pressure vessel usage we try to find out the precise nature of the job in order to establish the precise material property requirements'. One difficulty appears to be that of getting a view of the pressure vessel industries' requirements (see para 43). With regard to the fabricators' complaints, without detailed knowledge of the information (which was unobtainable) accurate comment cannot be made. However, comparing the different emphasis on R & D subjects between the two parts of the industry it is likely that the difference in attitudes arises from lack of communication on the problems created by fabrication and welding. If this is true then there must be doubts of the extent to which the steelmaker can develop relevant fabrication procedures in present circumstances.

32. Comparatively little information was obtained on the financial gains arising from R & D. Only two organisations gave quantitative answers, the remainder were qualitative only (in terms of reliability, more economical production, ability to tender, etc.), with 12 organisations producing comments ranging from 'it is very difficult' to 'it is not possible to give details of financial gains from R & D'. It seems that for some R & D cost savings cannot be estimated. This would be expected with basic research but the evidence here is that most organisations have difficulty even with applied research. One or two organisations stated that financial gains could be spelt out but only with considerable effort. However, for the majority of organisations, it is clear that actual cost savings are just not obtainable. Thus a study of the cost-effectiveness of R & D cannot be made from the information to hand, and in most cases the necessary information is probably not obtainable. A parallel situation is evident in the costing of R & D.

33. To summarise, much of the R & D has been applied to some degree but the gains obtained from it cannot be assessed quantitatively. Very few organisations appear to make any attempt to obtain any form of profit and loss account of R & D. In the majority of industrial organisations R & D is carried out as an insurance to avoid loss, to keep ahead of demand for new processes or products and to give an effective trouble shooting service. The use of R & D obtained by other organisations does not appear to be great and that produced by BWRA (now the Welding Institute) is the only R & D quoted as being applicable to any significant extent. Interchange or application of R & D between industrial organisations is small, probably restricted by lack of publication of results, and there is evidence that the lack of a unified approach between steelmakers and pressure vessel manufacturers presents a form of barrier to the application of R & D.

CHAPTER 6

Subjects suggested for future R & D

34. The intermediate and high effort level organisations were asked to give details of the main fields in which more R & D should be undertaken during the next five years. The suggestions have been gathered together under general headings (although there is some overlap between subjects) and are listed in Annex D. Each sub-topic is arranged in approximate order of popularity, the number following indicating how many organisations have suggested the topic. There were a large number of suggestions, no doubt encouraged by the lack of restriction on where the R & D was done and many organisations noted that they could not tackle the problems and that many were beyond the scope of any single organisation.

35. R & D related to design aspects produced more suggestions than any other topic, confirming the relative balance between subjects shown in Fig. N(5). There is a strong demand for work leading to rationalisation of design for flanges, nozzles and fittings. This is almost entirely from pressure vessel manufacturers with support from one university, the general comment being that several design methods exist and the most economic is not necessarily used. Advanced stress analysis methods are required to cope with geometrical discontinuities, multiaxial loading and creep and fatigue. One company believed that general facilities should be developed for 'reliable, accurate and fast theoretical analysis' which can be used to rationalise codes of practice, and which left the designer free to concentrate on the general design approach and details. These 'advanced methods' to some extent duplicate other specific proposals for low cycle fatigue, creep, plastic and limit analysis.

36. In the welding field priority is suggested for assessment of the behaviour of welded joints. In several instances the development of a test which can accurately predict the behaviour of plate, weld metal and weld embrittled regions is proposed. The main criterion proposed is relative to brittle failure but creep, fatigue and corrosion are also considered worthy of investigation. Large scale development directed towards applying the newer welding methods to practical production is suggested along with the use of the proposed test to assess the suitability of any new method. Methods for the production of fine grained electroslag welds would aid economical production; it might be noted that this work is not proposed by those pressure vessel manufacturers already engaged in development in this field. General development is called for on automatic processes for specific applications and on improved consumables. One large fabricator suggested that 'For the manufacturer of the thinner range of pressure vessels, reports of a practical nature dealing with the available and developing welding processes' would offer hopes of making industry more competitive: such practical reports hardly seem likely to be forthcoming from an industry reluctant to publish, especially where know-how is involved.

37. R & D directed towards an understanding of the significance of defects has been proposed by practically every type of organisation and, in terms of numbers, leads all other subjects. Background knowledge relative to brittle, creep or fatigue failure is involved but the application of quantitative data would lead to more realistic inspection standards, with possible economic advantages. The main emphasis is on defects in

welds and fabricated structures. Relatively few suggestions are made as to how this understanding can best be achieved but general test programmes are suggested from which the standards could be defined and also the use of prototype testing and correlation with service experience. The fear that inspection standards for steel products are too rigorous is expressed by two steelmakers, particular mention being made of defect limitations in the body (non-welded area) of the plate. Coupled with the understanding of defects is the need to develop NDT methods. Several organisations favour the development of ultrasonic methods although most other methods are mentioned and stress is laid on the practical application relative to pressure vessels.

38. Rationalisation of inspection methods and practice is suggested as being necessary to increase competitiveness abroad and raising efficiency. One organisation considers that 'competitiveness abroad could be assisted by making shop inspection by an independent authority mandatory in the relevant BS and possibly augmenting this with the Factories Act'. Another advocates a similar system to the AID inspectorate and 'also that the qualification standards, training and updating of pressure vessel inspectors should be the responsibility of the central pressure vessel authority'. Both organisations present strong views on the lack of efficiency and confidence in the existing diverse system. Another organisation comments that one body should be responsible for rule making and interpretation of standards.

39. Collection of material data remains as a popular suggested activity. Fatigue and the interaction of creep and fatigue account for a substantial proportion of the unknown quantities. In agreement with their current R & D programme, pressure vessel manufacturers make comparatively few proposals under these headings. Requests for a better definition of material properties of interest to the pressure vessel manufacturer are made by four steelmakers; this is discussed further in para. 43.

40. The demand for development of new materials is apparently small; this contrasts with the comparatively large effort predicted by all types of organisation in the first questionnaire. However in this grouping only new materials are considered and substantial development of existing materials is probably proposed. New materials are suggested mainly by users and relate to higher strength weldable structural steels and to the need for improved quality. A deterrent to the use of new materials is the scale of 'work necessary to relate the properties of a new steel welded in various ways to the various forms of service failure'. This and similar problems of general acceptance—by inspection authorities, insurers etc. probably account for the comparatively small interest in new materials by pressure vessel manufacturers.

41. Relatively little enthusiasm exists for R & D on fabrication problems or new types of vessels although individual viewpoints on these may be as strong as on more popular subjects. Most of the proposals are aimed at improved economy, with a steelmaker adding a plea for the development of fabrication methods for quenched and tempered steels. The small amount of interest in novel techniques for manufacturing vessels (ie such aspects as multilayered vessels rather than weld procedure development) is in accord with the low effort currently applied to this subject (Annex C).

42. Rationalisation of material and design standards is called for by pressure vessel manufacturers, materials manufacturers and an insuring body. The ultimate objective of a universal standard is sought with the belief that this could be achieved by universal recognition of ISO requirements. Economy would result since a 'pressure vessel manufacturer may be called upon to work to any one of them' and 'if factors of 4 exist in the

thickness of steel to be used . . . the design and theory of pressure vessel construction needs to be developed much further'. Many of the detailed design aspects discussed in para. 35 and other comments, for example, on the need to standardise testing techniques and on the inadequacy of recent design standards, lend weight to the need for more uniformity.

43. Probably the most important of the topics is the dissemination of information on R & D. A university department comments that efficiency would be raised 'if information which has been available for anything up to a century could be disseminated among . . . some of our manufacturing companies'. A manufacturer believes that a central translating authority of foreign standards and technical information would reduce duplication of effort. While this general lack of communication may result in inefficiency it appears that a pressing current problem is the lack of appreciation of the needs of other types of organisations in the industry. A fabricator's complaint of receiving comparatively little information from the steelmakers is counter-balanced by four steelmakers asking for a definition of the pressure vessel industry's requirements of a steel. The fabricator in turn comments 'there is an urgent need to identify the needs of end-users in the future'; such information could be used to establish essential R & D programmes for all types of organisation. If these views reflect the opinions of the majority of the industry then there is an urgent need for a forum where all requirements of the industry can be discussed.

44. Several conclusions can be drawn from the proposals made. In general the distribution of the subject matter is not dissimilar to the R & D proposed by all types of organisation (Fig. N(5)). However, the greater freedom (of not being committed to do the work) has moved the emphasis on some topics. In particular large scale R & D necessary, for example, in understanding the significance of defects, in standardisation of design standards in rationalisation of design of pressure vessel fittings and in development of newer welding techniques has been strongly supported. Some half dozen organisations suggested that much of this could be done by prototype or model testing, recognising that this work was generally beyond the capabilities of any single organisation.

45. The proposals made in the second questionnaire give similar major topics requiring investigation to those found by Fessler and Stanley(1) who used a much smaller sample in deriving their statement of problems. The trend in the present analysis, to lay greater emphasis on problems related to welding and to defects, is probably due to the greater representation of pressure vessel manufacturers and the proportionately lesser representation of the universities. In discussions to the Fessler and Stanley paper, where the out-of-balance of manufacturers was somewhat redressed, more emphasis was laid on such topics. The difference in viewpoint between universities and manufacturers was brought out in discussion of the paper and again highlighted the need for communication of information. This was not agreed in the discussion but the evidence presented in this survey is that improvement in dissemination of information is essential for effective R & D. In conclusion it might be noted that where there are increases in the extent of R & D proposed for the future (Annex C and para. 15) the subjects are coincident with the more popular proposals in this questionnaire. Thus to some extent work is being directed where it is most needed.

(1) H. Fessler and P. Stanley: 'Current Pressure Vessel Problems' and discussion 10th January, 1968. *Proc. Inst. Mech. Eng.* Vol. 182, Part 3F.

CHAPTER 7

Views on the formation of a UK organisation similiar to PVRC

46. Opinions were obtained from 39 of the larger organisations on the possible benefits to the UK pressure industry from the formation of an organisation similar to the USA Pressure Vessel Research Committee (see Annex F). Thirty-one organisations including all pressure vessel manufacturers, considered that such an organisation would benefit the industry and only three companies felt it would be of little value. These three objected essentially on the grounds that it would involve duplication with existing committees and confuse attempts to rationalise UK standards, and that it would proliferate inefficient committee control of the industry.

47. Seventeen of the organisations thought that such an organisation should provide:

(a) technical planning of collaborative R & D work,

(b) financial assistance and control of such work,

(c) dissemination of information.

Comment on these three possible functions was requested from each organisation. Reservations were expressed by some on the advisability of technical planning of collaborative R & D work, particularly in detail.

48. Many views were given on the possible structure of a PVRC and its relationships with other organisations. Ten organisations made suggestions falling within one of the following categories: (1) to work in conjunction with standards organisations, (2) an extension to an existing research association, (3) under the control of one or more of the Engineering Institutions.

49. Several proposals stressed the need for co-operation with (or even combination with) standards organisations so that research could be rapidly assimilated into design standards. Support for this view was also given in proposals for R & D (Chapter 6) relating to design features and standards. One company considered that in addition to PVRC functions the organisation should undertake 'rule-making and the co-ordination of the action of insurers regarding their interpretations of design standards and inspection processes'.

50. The majority view on financing a PVRC organisation was that costs should be shared, not necessarily equally, between Government and industry. Minority and conflicting viewpoints were from a large fabricator that it should be by Government finance alone— '. . . the volume of work calling for such expenditure is not very great', and from a steelmaker that it should be by finance from the pressure vessel industry alone— '. . . the pressure vessel industry will take greatest cognisance of results for which it has had to pay to obtain'. Very few comments were made on possible mechanisms for raising the finance from industry.

51. It is concluded that there is a very strong support for an organisation functioning similarly to PVRC. Taking the majority view such a committee would be financed by both Government and Industry and would be closely integrated with standards writing bodies.

ANNEX A

Second questionnaire

Question 1. Please give a brief description of each item, giving where possible an approximate estimate of qualified effort and/or cost, of the principal areas of R & D work related to pressure vessels, their materials or methods of fabrication, in which your organisation has been engaged over the period 1962–6 and/or in which your organisation is currently engaged. Please indicate, with references, how much of this work has been published either in the open literature or circulated to collaborative organisations within the industry, eg trade organisations, research associations, standards bodies, etc.

Question 2. Please give details of examples where the results of R & D obtained from your own organisation or other (named) organisations (eg Research Associations), have been applied within your own organisation. Please indicate where the R & D has led to changes in standards or procedures and if possible give information on the financial gains or improvements in quality obtained as a result of any R & D project.

Question 3. Give details of the main fields in which you would like to see more R & D done in the period 1967–71. Do not limit your replies to problems which can be tackled within your own organisation. Please indicate after each item whether you propose such work:

(a) to raise efficiency in the PV industry,

(b) to increase competitiveness abroad,

(c) to increase the quality or to reduce the possibility of failure of the product,

(d) to provide background information.

Question 4. Do you consider that the UK pressure vessel industry would benefit from the formation of a similar organisation to the USA Pressure Vessel Research Committee. If so please indicate whether you think it should provide:

(a) technical planning of collaborative R & D work,

(b) financial assistance and control of such work,

(c) dissemination of information.

Have you any views on how the PVRC organisation could be adapted to UK conditions?

ANNEX B

Methods adopted to obtain estimates of effort

Effort weighting

1. An estimate can be obtained of the *overall* effort on pressure vessel R & D for each of the two periods 1962–6 and 1967–71. This is made by multiplying the number of organisations by a weighting factor based on answers to the questionnaires. Average man-years have been taken for the low and intermediate effort levels (para 2) organisations. For the high effort level organisations (>50 man-years over 5 years) no upper bound of effort was specified and hence any average figure taken would be conjectural. For this high effort level the minimum effort of 50 man-years has been taken, this conservative value being considered preferable to overestimating effort to an unknown extent. Thus the applied effort for each of the low, intermediate and high effort level organisations has been taken as 5, 25 and 50 man-years respectively for each 5 year period. The accuracy of computations based on these applied effort levels depends on the assumption that the averages taken are reasonable and that replies were obtained from all organisations active in R & D related to pressure vessels.

Effort index

2. Ideally this survey should permit an indication not only of the overall R & D but also the effort (expressed in man-years or similar units) directed towards any research topic. Information from the present survey is insufficiently detailed to do this accurately since in the interests of simplicity the questionnaire did not ask for the overall effort of an organisation to be broken down to the efforts applied on individual topics. Consideration of numbers of organisations gives only a crude impression of the effort expended on a particular topic since the contributions made by individual organisations vary between wide limits. To permit some indication of effort, the numbers of organisations have been multiplied by the factors detailed here to give an 'effort index'. Each sub-area has been weighted by a factor of 5, 25 and 50 respectively for each low, intermediate and high level organisation indicating work done or proposed. For work carried out in the 'past' and 'present' the overall effort level quoted for 1962–6 has been used; for 'immediate future-sanctioned' and 'long term future' the effort level for 1967–71 has been used. In several replies no estimate has been made of the effort expected in 1967–71 although replies in sub-areas indicate that work is proposed in this period; in these instances the effort level quoted for 1962–6 has been assumed to apply for the period 1967–71. The 'effort index' in each sub-area is produced by dividing the product of the number of organisations and their respective average effort by 46 (the number of sub-areas covered). This produces a convenient two-digit number the accuracy of which is not precisely known. The major errors are due to the assumption that the effort contributed by each organisation in each sub-area is *one forty-sixth* part of their overall effort and the assumption that work in each sub-area demands identical effort. The error due to the first could be reduced by dividing the average effort by the number of areas in which work was proposed; however this is not considered worthwhile since the second assumption would probably override any increased accuracy (work on experimental stress analysis, for example, requiring much greater effort than

tensile testing). It should be emphasised that 'effort index' is a crude approximation the worth of which is solely to permit some indication of relative efforts between subjects on which several organisations are applying widely differing effort levels.

ANNEX C

Effort applied to each subject

1. The number of organisations and the effort applied (in terms of effort index) have been examined for each sub-area. The data given in this survey have not been broken down in terms of number of organisations of each type, or in each effort level category or with respect to time. Areas are arranged in approximate order of decreasing effort and the discussion of each is prefaced by listing the sub-area with the effort index and number of organisations currently engaged in R & D. Changes (with time) greater than 2 in effort index or 5% in numbers of organisations have been taken as significant. The criterion used is a comparison of 'present' with the maximum of either 'immediate future' or 'long term future'. The latter is compared only when it does not show the usual rapid fall off. Limitations on the validity of comparison of effort indices remain as discussed in Annex B.

2. *Area* 5. R & D *associated with design aspects*

	Effort index	No. of organisations
Stress analysis		
Elastic	27	55
Plastic	19	36
Creep	12	26
Studies aimed at establishing relevant failure criterion:		
Fast and brittle fracture	20	31
Fatigue (endurance and low cycle)	19	34
Creep	16	26
Yield and bursting	23	38
Relationship of defect size to failure condition	12	20
Application of computer techniques	21	39
Type of work involved in above studies:		
Theoretical	28	56
Laboratory tests on specimens	29	56
Tests on model or full size components or vessels	28	53

3. The three final sub-areas in para. 2 qualify the type of work involved and represent a summation of work on the other topics. Both in terms of numbers of organisations and effort, work on design aspects of pressure vessels appears to be equally divided between theoretical work, specimen testing and model testing. An increase in the effort devoted to specimen testing (to effort index 32) is predicted for the immediate future although the number of organisations participating will decrease slightly. The effort index for both theoretical work and model testing remains constant with time. Appreciation of the significance of the numbers of organisations and the magnitude of the effort index may be assisted by recording that these values represent the highest obtained in any sub-area.

4. Elastic stress analysis is done by a large number of organisations and has a high effort index. Plastic stress analysis is less and there is considerably less effort applied to analysis in the creep range. However both plastic and creep analysis show an increase in effort predicted for the future. Creep analysis increases to an effort index of 15 for both immediate and long term future; plastic analysis decreases slightly for the immediate future and non-typically increases significantly for the long term future, to an index of 22. In both cases these increases are accompanied by a slight decrease in the number of participating organisations. Reduction in the predicted amount of elastic stress analysis equates it to the effort index expected for plastic stress analysis.

5. Work aimed at establishing failure conditions is at a fairly high level. Studies of defect size and creep are the least popular aspects at present but increases in work are predicted for both, the effort indices rising to 15 and 19 respectively. The creep work thus confirms the increase in creep stress analysis forecast. All other work on failure conditions remain constant over the period under review.

6. Computer Techniques are used by about 75% of the organisations interested in Design Aspects, although in terms of all organisations involved in R & D only about 30% are using computer techniques. The effort remains constant for the future but an unusual feature is that the 'present' effort is significantly greater than that for the 'past'.

7. Universities, pressure vessel manufacturers and public corporations provide the greatest number of organisations working in this field. With one small exception the R & D activity of consultants is limited to theoretical aspects of stress analysis. The categories of organisations do not change significantly with time but the total numbers at the low effort level decrease markedly in the future (this trend is consistent through all areas). The large effort applied to the subject as a whole is due to the high proportion of high effort level organisations.

8. *Area 2. Determination of data on pressure vessel materials*

	Effort index	No. of organisations
Yield and tensile strength at temperature	27	49
Creep and rupture	25	46
Fatigue (endurance and low cycle)	16	29
Fracture toughness	23	40
Corrosion and oxidation	19	35
Properties of weldments	24	39

9. The effort devoted to fatigue and corrosion is less than for the other subjects, all of which are running at an approximately equal level. These experimental determinations take up more effort, and interest more organisations, than 'Studies aimed at establishing relevant failure criterion' (Area 5). The greatest difference exists in creep and rupture where the effort on determination of properties is about 50% greater than that applied to studies of failure criteria. Determination of data appears to be taking an approximately constant level of effort over the whole 10 year period under review. The number of organisations proposing to work in the future on determination of tensile, creep and rupture properties decreases but this is not accompanied by an appreciable decrease in effort.

10. The materials manufacturers have the greatest number of organisations active in all of these topics except fracture toughness and properties of weldments where pressure vessel manufacturers take the lead. The spread of the work between other categories or organisations is fairly uniform except for properties of weldments where, in addition to pressure vessel manufacturers doing most of the work, the contribution of the universities has decreased significantly, only one department showing interest.

11. *Area* 1. *Development of materials for pressure vessels*

	Effort index	No. of organisations
Laboratory investigations	25	43
Prototype or production studies	14	22
Mild and low alloy steels	24	40
High alloy steels and stainless steels	21	35
Aluminium alloys	2	4
Other non-ferrous metals	7	13
Other materials	7	13
Weld metals	15	23
Cladding materials	9	13

12. The ratio of laboratory work to production studies is about 2:1. The total number of organisations and the number at a constant effort level change in the same proportion, but the proportion varies by type of organisation. Industrial users of pressure vessels split their effort almost equally between laboratory and production work; materials manufacturers give a ratio of 5:3 and pressure vessel manufacturers approach the ratio of 2:1. All other categories have not more than one organisation working on production studies. The balance does not change in the future although the production work sanctioned for the immediate future decreases slightly whereas the laboratory work remains at the same level as at present.

13. The greatest effort by far is concentrated on steels, mild and low alloy steels taking slightly more effort than high alloy and stainless steels with materials manufacturers providing more effort than any other category of organisation. Pressure vessel manufacturers lead in the development of weld metals with materials manufacturers and pressure vessel users providing the only other significant contribution. This trend is similar to that found for determination of properties of weldments (para 10) again only one university department being engaged in this field. Development of cladding materials takes up less effort and has similar sponsors to work on weld metals although pressure vessel users are less active. Development of non-ferrous alloys and other materials is occupying very few organisations and takes a correspondingly low effort, the bulk of which is provided by pressure vessel manufacturers rather than, as in the case of steels, by materials manufacturers. 'Other materials' are developed by a comparatively large number of universities; but details of these materials were not given. The effort for development of all materials generally continues at the existing levels. The one exception is the decrease expected for 'other non-ferrous alloys'; again details of the materials were not given.

14. *Area* 3. *Development of welding processes and equipment for pressure vessels*

	Effort index	No. of organisations
Laboratory investigations	22	34
Improvements in currently accepted techniques during production	19	33
Development of new techniques for production application	17	29

15. The effort devoted to laboratory investigations is only slightly greater than that devoted to other aspects (in contrast to the balance in Materials Development). The effort and number of organisations is virtually constant over the ten year period. There is a high proportion of high effort level organisations engaged in the work and pressure vessel manufacturers greatly outnumber all other categories of organisation. Universities, Government departments and inspection organisations provide little or no effort for most of the topics.

16. Mention should be made of the low level of effort (one organisation) supplied by manufacturers of pressure vessel equipment; this is because of the method used to classify organisations. If 'manufacturers of pressure vessel equipment' was taken as the main category for each organisation including this as a description of their organisation, then a total of 14 organisations could be included. Of these 6 are working on this topic and contributing an effort index of 4 to each sub-question. On this basis equipment manufacturers can be regarded as producing about 20% of the total R & D on this subject. Equally, electrode manufacturers are classed as 'manufacturers of materials'; thus their development work on welding processes will be included under this heading.

17. *Area* 4. *Development of quality control techniques*

	Effort index	No. of organisations
Laboratory investigations into new NDT techniques	21	30
Techniques for improved control of material quality	17	27
Techniques for assessing weldments	20	26
Improvement in currently accepted techniques during production	18	28
Development of new techniques for production application	18	24
Development of equipment	12	17
Assessment of NDT techniques eg defect sensitivity	19	30

18. Roughly equal amounts of R & D related to quality control are devoted to each topic except that of development of equipment. The main effort on equipment is provided by pressure vessel manufacturers and, to a lesser extent, by materials manufacturers. As with the development of welding processes, some quality control equipment manufacturers are contained under these headings and the apparent low contribution is misleading. However, the R & D applied to equipment development for

quality control is comparatively low; this could be due to the omission of manufacturers of scientific instruments from the distribution of questionnaires. The remainder of the topics are covered to some extent hy most categories of organisation with pressure vessel manufacturers heading the list.

19. The effort predicted for the future is approximately the same as that currently employed. The only exception is that for 'Techniques for Assessing Weldments' where the effort index relating to the immediate future is just significantly less than that for the present. This contrasts with other work on development of weld metals and testing of weldments for which the effort index remains constant with time.

20. *Area 6.* R & D *into techniques for manufacturing components*

	Effort index	No. of organisations
Laboratory trials	21	32
Works trials related to improvements in accepted techniques	14	22
Works trials and prototype studies of new techniques	14	20

21. Effort indices in this and subsequent questions are at relatively low values. Laboratory trials occupy 50% more organisations than works trials, a lower ratio than was found in Materials Development (para. 13), but higher than that found in Development of Welding Processes (para. 15). The effort devoted to trials in 'currently accepted techniques' is identical to that for 'new techniques'. The equivalence of R & D effort between 'new' and 'currently accepted' techniques is also found in Welding Processes (para. 15), Quality Control (para. 18) and Manufacture of Pressure Vessels (para. 24). In several instances the organisations contributing to new techniques differ from those concerned with improving existing techniques.

22. Future R & D on component manufacture involving works trials is expected to remain at the present level of effort. A significant decrease is forecast for laboratory trials in terms of hoth reduction in effort and numbers of organisations.

23. *Area 7.* R & D *into techniques for the manufacture of pressure vessels*

	Effort index	No. of organisations
Lahoratory investigations	6	12
Works trials related to improving currently accepted techniques	7	10
Works trials and prototype construction related to new techniques	7	12

24. The overall effort applied to this subject is extremely small. The division of laboratory investigations covers universities, public corporations, materials manufacturers, pressure vessel manufacturers and pressure vessel users in equal numbers. Works trials are left largely to the pressure vessel manufacturers and materials manufacturers, the former contributing about two-thirds of the effort. The level of R & D is expected to stay constant.

25. *Area* 8. *Other* R & D *work relevant to pressure vessels not covered by above*

	Effort index	No. of organisations
Assessment after installation on site	13	21
Production engineering techniques for improving manufacturing economy	7	14
Other aspects	2	3

26. Assessment on site is carried out by a wide range of organisations; users and manufacturers of pressure vessels are numerically equally prominent. In the future the effort and number of organisations will remain at the present level. Production engineering techniques are investigated by 14 organisations, 11 of these being pressure vessel manufacturers. Since only 2 of these organisations are in the high effort level group, the effort applied to production engineering is low. There is a slight increase in planned effort for the immediate future; this is entirely due to 2 organisations proposing to increase their overall effort from the intermediate to the high effort level in this period and hence does not necessarily represent a large change of applied effort on production engineering.

ANNEX D

Suggestions for subjects requiring more R & D in the period 1966-71

A. Design and stress analysis

		(No. of organisations noting subject)
A1.	Improvement and rationalisation of flange design	5
A2.	Rationalisation of nozzles and fittings	5
A3.	Advanced theoretical stress analysis (backed up with materials data)	4
A4.	Low cycle fatigue	5
A5.	High temperature design (creep, fatigue and interaction, thermal stresses)	3
A6.	Plastic stress analysis	2
A7.	Individual proposals: design of vessel supports; computer programmes; design of large bore closures	3 (1 of each)

B. Welding developments

B1.	Assessment of behaviour of welded joints (toughness, high temperature properties, fatigue, corrosion)	6
B2.	Application of newer welding methods (electron beam, laser, plasma arc, friction)	4
B3.	Electro-slag welds without normalising (fine grain weld)	4
B4.	Limits necessary in post-weld heat treatment (metallurgical and residual stress)	4
B5.	General welding development (improved consumables, automatic processes)	3
B6.	Individual proposals: low temperature tough weld metal; automatic welding of nozzles; more precise determination of 'weldability'; weldability in thick sections without preheat; local stress relief; build-up of stresses during welding; causes of welding defects; testing dissimilar metal joints; practical reports on welding thinner pressure vessels	9 (1 of each)

C. Inspection and defects

C1.	Understanding of significance of defects (welds and base materials)	12

		(No. of organisations noting subject)
C2.	Development and application of NDT methods (mainly ultrasonic)	8
C3.	Rationalisation of inspection systems	2
D.	*Material data*	
D1.	Ineraction of fatigue and creep (including multiaxial stressing, prototype testing)	8
D2.	Fracture toughness (fracture mechanics and brittle fracture)	6
D3.	Fatigue data (including welded joints)	4
D4.	Better definition of materials properties for use in pressure vessels	4
D5.	Hydrogen embrittlement	2
D6.	Individual proposals: standardisation of tests; fatigue of thick tubes; properties of large forgings; accumulation of data on properties of forgings; stress corrosion behaviour of high strength steel; data on collapse of vessels during heat treatment	6 (1 of each)
E.	*Materials development*	
E1.	Weldable high strength material (quenched and tempered and > 50 tsi steels, 'materials', and forgings)	5
E2.	Individual proposals: creep resistant and thermal shock resistant materials; improved cleanliness and homogeneity of structural steel	2 (1 of each)
F.	*Fabrication methods*	
F1.	Forming operations (using materials properties)	2
F2.	Individual proposals: forming methods for quenched and tempered steels; cheap fabrication methods; forming of branches; manufacture of tube plates; methods for use of high strength/weight non-ferrous alloys	5 (1 of each)
G.	*New pressure vessels*	
G1.	Multilayer vessels	2
H.	*Design standards*	
H1.	Rationalisation of materials and design standards	5

		(No. of organisations noting subject)
H2.	Individual proposals: design standards for external pressure design; high temperature design basis	2 (1 of each)

J. Miscellaneous

J1.	Individual proposals: dissemination of information; translation service especially foreign standards and technical information; strain measurement techniques; information on future needs of end-users	4 (1 of each)

ANNEX E

Science Research Council: list of grants (as at March 1967) supporting work in the field of pressure vessels

1. *Pressure vessel design and behaviour*

Dr. F. A. Leckie Cambridge University	'Preparation of Design Data for Pressure Vessels and Other Structures' £3,800 over 3 years
Dr. P. Stanley Nottingham University	'Stresses at Oblique Holes in Thick Plates' £3,300 over 3 years
Dr. L. E. Culver ICST (London)	'Expanding of Tubes into Water-Tube Boilers' £1,000 over 1 year
Dr. H. Fessler Nottingham University	'Stresses and Deformations in Taper-Hub Flanges' £9,200 over 3 years
Mr. C. Ruiz Sheffield University	'High Strain Fatigue and Incremental Collapse of Pressure Vessels' £1,700 over 3 years
Mr. C. Ruiz Sheffield University	'Application of Limit Analysis to Designing Reinforced Openings in Pressure Vessels' £1,700 over 3 years
Dr. C. E. Turner ICST (London)	'Design Applications of Computer Programmes of Elastic-Plastic Stress Analysis' £8,700 over 3 years

DESIGN AND BEHAVIOUR TOTAL = £29,400

2. *Material properties*

(of interest, but *not* restricted to the field of pressure vessels)

Prof. J. M. Alexander and Dr. G. B. Webster ICST (London)	'Precise Predictions of Time-Temperature-Dependent Behaviour of Engineering Components' £50,000 over 4 years
Prof. W. Johnson UMIST	'Biaxial Creep Testing' £8,900 over 2 years
Mr. W. W. Mackie Glasgow University	'Two Aspects of the Creep Behaviour of Metals' £8,800 over 3 years
Mr. B. A. Marlow UCSW (Cardiff)	'Deformation and Stress Redistribution in Simple Stress Systems due to Creep' £4,900 over 3 years

Prof. J. L. M. Morrison Bristol University	'Fatigue of Metals subjected to Triaxial Stress' £9,600 over 4 years
Dr. R. L. Apps COA Cranfield	'Relation between Metallurgical Structure and Properties of the Weld Heat-Affected Zone in Low Alloy Steels' £10,000 over 3 years
Prof. B. A. Bilby Sheffield University	'Elastic and Plastic Fields Round Inhomogeneities' £20,000 over 3 years
Prof. B. Crossland Queen's University (Belfast)	'Correlation of Creep of Thick Walled Cylinders under Internal Pressure with Tension and Torsion Creep Data' £16,500 over 5 years
Prof. B. Crossland Queen's University (Belfast)	'Metallurgy of Explosive Welding' £22,500 over 3 years
Prof. H. Ford and Dr. C. E. Turner ICST (London)	'Fracture Mechanics' £29,700 over 4 years
Dr. P. Hancock Glasgow University	'Effect of Atmosphere on the Mechanical Properties of Materials at High Temperatures' £18,700 over 2½ years
Dr. R. Kennedy Strathclyde University	'Effect of Vanadium Additions on the Strength and Fracture Properties of Steel' £6,200 over 3 years
Dr. R. N. Parkins Newcastle University	'Stress Corrosion Cracking of Low Carbon Steels' £13,000 over 3 years
Prof. N. P. Petch Newcastle University	'Brittle Fracture of Metals' £121,500 over 5 years
Prof. A. L. Roberts Leeds University	'Mechanisms of Delayed Fracture and Creep at High Temperatures in Ceramics for Engineering and Chemical Engineering Uses' £13,800 over 3 years

MATERIAL TOTAL = £354,800

3. The above research may be compared with the overall level of support by the SRC in the various fields of engineering (490 grants totalling £5·4M) and in metallurgy and materials (196 grants totalling £2·4M), both figures referring to grants current as at March, 1967.

ANNEX F

Notes on the Pressure Vessel Research Committee of the USA

Source: PVRC annual report for 1967

1. The Pressure Vessel Research Committee was organized in 1945 by the Welding Research Council. The function of PVRC is to sponsor co-operative research on nonproprietary problems in the pressure vessel field that are of current and future importance to industry and standards writing bodies.

2. PVRC receives financial support from a number of individual companies concerned with pressure vessels and components, and from trade associations, such as the American Iron and Steel Institute, the American Petroleum Institute, the American Gas Association, and the Edison Electric Institute. A number of PVRC research projects are supported partially or totally by Government Agencies such as the Atomic Energy Commission and the Navy Department.

3. Nearly 200 well-qualified engineers and scientists serve on the some 30 committees within PVRC. These men represent industry, government agencies, universities, research organizations, and engineering societies. Thus, each PVRC project is benefited by the combined viewpoints of a number of sources related to the pressure vessel field.

Organization

4. The Pressure Vessel Research Committee is made up of the Main Committee, Executive Committee, Program Evaluation Committee and three Divisions — Materials, Design and Fabrication. Each division has several subcommittees which are listed below:

Materials Division

- Pressure Vessel Steels
- Pressure Vessels for Nuclear Applications
- Hydrogen Embrittlement
- Effective Utilization of Yield Strength

Design Division

- Shells
- Stresses in Ligaments
- Reinforced Openings and External Loadings
- Bolted Flanged Connections
- Stress Indices for Piping, Pumps and Valves

Fabrication Division

- Preheating and Postheating
- Plastic Fatigue Strength
- Thermal and Mechanical Treatments
- Significance of Weld Discontinuities

5. The Main Committee meets annually to review progress during the past year, to hear plans for the coming year, and to act on the final budget submitted by the Executive Committee. The Executive Committee serves as the governing body for the Divisions, which make recommendations to the Executive Committee on the need for new projects or the continuation of existing projects. Recommendations are also made as to the amount of funds needed to sponsor these programmes. The Divisions appoint Subcommittees to deal with the specific items of research. Subcommittees plan research projects, prepare interpretive reports, and guide the actual research work, which is carried out in universities and nonprofit laboratories. When the need arises, a Division or Subcommittee appoints a Task Group to be responsible for a specific item. Task Groups usually accomplish a specific purpose and are then disbanded or, if warranted, are elevated to sub-committee level. In some cases a Task Group may guide a continuing project.

6. Over 100 projects have been completed since the first work initiated at Purdue and Lehigh in 1946. The results of these projects are presented in the some 157 technical reports listed in the Bibliography of the Annual Report.

Budget for 1967–68

7. The preliminary PVRC budget for the fiscal year (1967–68) involved a total expenditure of $301,550. It is expected that $129,550 will be received from Industry and $172,000 from Government sources. The budget is divided as follows: Materials Division—$15,400; Design Division—$219,650; Fabrication Division—$39,000; and Administrative and Publication Expenses—$27,500. The above budget figures do not include a sum of funds, substantially greater than the total PVRC budget, which will be contributed by the AEC and industry for work during the coming year on heavy-section steels (described under the Materials Division Subcommittee on Pressure Vessel Steels) and on piping, pumps and valves (described under the Design Division Ad-Hoc Committee to Develop Stress Indices for Piping, Pumps and Valves).

Status of PVRC projects: 1967–68

8. Fig. F(1) shows diagrammatically the status of PVRC projects during 1967–8.

APPENDIX O

Interim report of a NCC working party on technical computer applications in the pressure vessel industry

(May 1968)

The Objectives of the Working Party may be broadly summarised as follows:

> To survey more fully the computer software already available in the pressure vessel field;
>
> To recommend programs or areas that could be developed to improve the use of computers within the industry, whilst remaining within the scope of design standards currently in use;
>
> To recommend programs that could be developed to produce improved designs whilst not restricted to conventional design standards;
>
> To make recommendations on any other factor relating to the application of computers in the pressure vessel industry.

Summary and recommendations

The development of computer-aided design in the pressure vessel industry has been considered by a working party of the National Computing Centre. Techniques, especially those which need to be pursued most urgently, were considered along with some of the problems of program production and distribution.

The working party is of the unanimous opinion that an increase in the use of computers for technical applications in the pressure vessel industry is desirable and would be of benefit to the industry. At this stage there would seem to be six steps which can be taken which would have a reasonable chance of success and the working party therefore makes the following recommendations for action:

1. To promote inter-company co-operation with current effort and the interchange of existing programs;
2. To arrange for the programming of standards used in pressure vessel design, to encourage programs for material selection and costing etc. and to investigate and recommend areas requiring financial support;
3. To increase the effort, at present being made by NCC, to seek out useful programs for stress analysis of pressure vessels and to assist in the distribution of these programs;
4. To approach BSI to discuss the modification of standards to facilitate the greater use of computer techniques and to consider standards or other criteria for use in programs;

5. To institute a series of short courses to assist design and managerial staff from the pressure vessel industry to understand the possible uses of computers and the contribution these could make to the industry;
6. To investigate the desirability of the development of engineering design systems with particular reference to pressure vessel design.

The working party hopes to be able to consider at future meetings each of these recommendations in greater depth and to be able to make detailed proposals concerning the implementation of these recommendations.

Introduction

1. The working party was set up by the NCC in response to a request from the Committee of Enquiry on Pressure Vessels, with the object of considering ways in which computers could be used to better advantage in the design and manufacture of pressure vessels. The working party decided to confine its activities solely to metallic pressure vessels. The membership of the working party is given in Annex A.

2. A preliminary NCC report: 'Initial Survey and Recommendations Regarding the Use of Computers in the Pressure Vessel Industry' (by G. C. Carroll of The National Computing Centre) was communicated to the Committee of Enquiry in August, 1967. The problems outlined in the preliminary report have been considered by the working party. The present interim report contains the views of the working party on these problems and gives six recommendations towards their solution. The working party expects to be able to consider each recommendation in more detail in the future and to make detailed proposals on how they might be implemented.

3. The present interim report is divided into two main sections. The first is concerned with design techniques which can be improved by using computers and shows areas in which effort might be concentrated. The second is concerned with program and package production and distribution.

Design techniques

4. Pressure vessels can conveniently be divided into two categories: conventional and special. Conventional pressure vessels are those which are normally designed in accordance with recognised standards and are particularly amenable to this method of design. Special pressure vessels are those which require design techniques which, while they may rely partly on standards, are generally of a more complex nature. The majority of pressure vessels are in the conventional category.

Conventional pressure vessels

5. The major advantage in designing with standards is the relative simplicity of the design operation. Most of the basic thinking has been done for the designer. However, it is still necessary to do the calculations associated with the standard and there is the major task of optimising the design, as far as possible, from the point of view of design costs, material costs and manufacturing costs. There is scope for the inclusion of large parts of design standards into programs, thereby relieving the designer of

the tedium of repeated calculations, and providing the opportunity of considering far more alternative designs than can be considered when relying on hand calculations. These programs also facilitate the rapid production of basic design information and tenders. This is a major advantage. Work on this type of program has been done by several people and it seems desirable to pursue the work further. The work would be accelerated and the resultant programs made more efficient if, in many cases, programmers could work from the theory on which some parts of standards are based, or at least use analytical expressions instead of charts, rather than work directly from the standards as they are currently presented. It would therefore seem desirable to have the basis of new and newly revised standards made available to organisations who are seeking to incorporate them in programs.

6. In addition computerised techniques can assist in the development of standards. Methods of analysis which require massive numerical work can now be used as a basis for standards. The accuracy of the calculations should reduce the error allowance which has to be made when compiling standards and, in general, should lead to reductions in material costs.

7. Alternatively, when the work involved in developing a standard using a computerised method is large, it may be better to use verified analysis programs for design purposes. However, the programs available would tend to be mainly elastic stress analysis programs and on their own they would not be sufficient to establish the integrity of a pressure vessel design. A designer would have to apply his own design criteria to the results whereas design criteria are partly included in standards. In general, if it is desirable to use verified analysis programs, it may be possible to establish the integrity of the design by appraising it in all failure aspects and applying a simple factor to each result. Alternatively, it may be possible to codify the design criteria to be applied.

8. Clearly, any changes in the presentation of standards or any developments to standards and the development of design criteria to be associated with verified standard programs would have to be achieved by the standardisation authorities working in close co-operation with designers, users and programmers.

Special pressure vessels

9. Various analytical methods, mainly for elastic stress, are available. Finite element elastic stress analysis programs have been written both by industry and by universities and these can either be generalised, and so cover a wide range of shapes, or be written to analyse a particular situation such as the intersection of a pressure vessel and its supporting structure. It may well be possible to develop a comprehensive series of finite element computer programs which would be useful to a wide range of users.

10. However, finite elements are not necessarily the best method of solution in all cases. Often other methods such as finite differences or boundary point collocation are more economical in computer running time. Also, it is often possible to use closed-form solutions for large parts of a pressure vessel structure provided it is properly idealised. It would seem to be desirable, therefore, to build up a comprehensive set of programs capable of providing solutions to many of the problems of elastic stress analysis likely to be met by pressure vessel designers. However, the point made in paras 5–8 regarding the application of design criteria to the results of analysis programs must be reiterated. Analysis programs provide only a basic but nonetheless valuable tool for the designer.

Associated design techniques

11. As well as using computers to assist with pressure vessel design using standard or analysis programs, there is scope to assist with material selection and manufacturing cost optimisation as a part of design. Manufacturing cost optimisation as part of design is clearly desirable but it is very difficult. The differences between one manufacturer and another make it impossible to have a completely general routine applicable to all manufacturers. However, optimisation techniques based on schedules of rates are used by some pressure vessel procuring companies and some manufacturers have included limited cost optimisation facilities in some design programs. The main problem seems to be that of determining how much generalisation is possible and how much must be left to individual manufacturers. However, even approximate methods, if wisely and critically used, have considerable value and it is to be hoped that more progress will be made in the near future.

12. Computers can also be used to advantage for heat transfer calculations. This subject is amenable to analytical methods of solution and several programs have been produced in the last few years with varying degrees of success.

Future design techniques

13. In the long term computer-aided design in the pressure vessel industry should benefit from new developments in the same way as other branches of engineering. An example of a technique which is likely to be valuable is cathode ray tube display and light pen use. Another is the input of shape descriptions to the computer. It may be that, in time, the computer can be programmed to accept shapes drawn with a light pen, recognise shapes, idealise them in several ways and automatically stress them for each idealisation.

14. An important area of development is in problem-oriented languages and system design. However, it would be inadvisable, at this stage, to attempt to produce a fully comprehensive system for pressure vessels. What is needed during the next few years is the establishment of a series of programs to assist in pressure vessel design and to investigate and further develop the techniques suggested in paras 11–12. There is also room for the simplification of input and output data as much tedious work is involved with most programs currently available.

15. It is to be hoped that, in time, a general engineering design system with several appropriate problem-oriented languages can be developed. The design system for pressure vessels with its appropriate problem-oriented languages would be a sub-set of the general system. But it must be recognised that this development will require a great deal of effort and will be very costly.

Development of design techniques

Program production

16. Programs and packages can be written and have been written by a variety of companies and organisations both under contract to others and for their own use. There is no reason why the present arrangements should not continue but with some improvements. Firstly, it is desirable that the effort should be co-ordinated in order to avoid wasteful duplication of effort and to ensure that effort goes, as far as possible, into the proper areas. Secondly, there are various short-term economic reasons why

companies do not produce more complex packages for their own use and why small companies do not produce any programs. In simple terms, the problem is that the short-term return is not great enough with large complex packages for individual companies to tie up such large resources. Therefore, in order to get the best progress from the industry, consideration should be given to the means whereby contracts to develop programs and packages could be placed with the industry and associated bodies.

Current effort

17. There is probably a wealth of useful programs available but being used perhaps infrequently by only one company or one department of, or branch of, one company. Many of these programms may not be in a suitable form for general use, but nevertheless it would seem to be desirable to make them as widely available as possible. Their existence, at least, should be publicised. It would be unfortunate if the effort of producing an expensive program were to be unnecessarily duplicated. Possibly the simplest way that this can be achieved is by means of the National Computer Program Index of the NCC.

18. The use of one company's program by another has both technical and commercial problems associated with it. However, provided goodwill is shown by all parties, it seems likely that the problems could be solved to the advantage of all concerned, not least the country as a whole.

Conclusions

19. Further development of computer-aided design in the pressure vessel industry would be beneficial to the industry. The products could be designed more quickly, more satisfactorily and could be cheaper to manufacture. The rate at which computer-aided design developments can take place is, however, not decided by the desirability of achieving a certain goal, but by society's capacity to set out towards the goal. That capacity is governed by the factors of:

1. The availability of the specialist personnel who must do the work;
2. The availability of financial resources to commission the work;
3. The industry's ability to accept the inevitable change in the structure and status of their design staff;
4. The existing design staffs' willingness to accept the inevitable change in their way of work;
5. The industry's willingness to treat the problem of commercial advantage to individual companies in a more liberal way.

20. Bearing in mind the increased productivity and the improvement in technology that can result from increased computer use in the industry, sufficient financial resources should be made available. Also, provided sufficient encouragement is given to technically competent people to enter the scientific computing field, as opposed to the commercial computing field, then the availability of staff should not constitute a problem. The sociological factors are such that any improvement is likely to produce a significant return. Consequently, there is a need for a considerable effort to be directed towards educating and informing managerial and engineering staff in the industry and who have no computer experience of the possibilities for computer-aided design.

ANNEX A

Membership of the NCC working party

Dr. D. M. Parkyn (*Chairman*) Computation Group, NCC

Mr. S. Kendrick (*Deputy Chairman*) NCRE Dunfermline

Mr. G. B. Griffiths	Babcock & Wilcox Limited, London
Mr. P. G. Henry	Davy-Ashmore Limited, Sheffield
Dr. R. T. Rose *or* Mr. H. Porter	John Thompson Limited, Wolverhampton
Mr. W. A. Rowley	Whessoe Limited, Darlington
Mr. J. S. Stoddart	Simon Carves Chemical Engineering Limited, Stockport
Mr. T. R. Gurney	BWRA Abington Hall, Cambridge
Mr. R. Hobbs	Tank & Industrial Plant Association, London
Mr. P. T. Daniel	ICI Limited, Wilmslow
Mr. C. H. A. Townley	Berkeley Nuclear Laboratories, Gloucestershire
Professor G. D. Galletly	University of Liverpool
Professor O. C. Zienkiewicz	University of Wales, Swansea
Mr. R. Carmichael	National & Vulcan Engineering Insurance Group, Manchester
Mr. B. Smethurst	Industrial Engineering Department, Computation Group, NCC

APPENDIX P

International comparison of inspection procedures

1. A detailed study of the inspection and pressure vessel approval procedures in various countries in the world was undertaken on behalf of the Committee. Evidence and information on inspection practices abroad were obtained from a number of individuals and organisations, and these are noted in the list of those providing written evidence given in Appendix A. The considerable help afforded by those contributing is gratefully acknowledged.

2. To carry out a comparative study of inspection organisations and practices in a number of different countries, a list was prepared of the aspects by which inspection practices could be characterised. The comparison between countries then became one of comparing individual aspects of each country. This may be done aspect by aspect, so that any unusual features may be readily identified. This approach had the advantage of permitting ready identification of the normal or majority practice in any given aspect as between the different countries.

3. The major aspects identified for study were the following:

(a) National Arrangements (organisation of inspection and lines of authority including statutory considerations);

(b) International Arrangements (international or reciprocal agreements, or other commitments);

(c) Internal Structure (management, costing, staffing, certification of inspectors);

(d) Direct External Relations (direct or delegated inspection, relationships with fabricators and users, fees, requirements for the report of failures);

(e) Indirect External Relations (standards writing activity both nationally and internationally);

(f) Working Documentation (inspection and/or design standards, certificates, use of approval stamp);

(g) Insurance Arrangements (civil liability of inspectors or inspection organisations for consequential damage etc, any affiliations with insurance business);

(h) Introduction of New Techniques (R & D, appeals, training of Inspectors);

(i) Impending Changes (arising from forthcoming national and international agreements, or changes in legislation).

4. Whilst information was obtained on a number of countries' inspection procedures, the following 16 countries have been selected for purposes of this appendix to illustrate the main characteristics of these procedures:

Australia
Austria
Belgium
Canada
Federal Republic of Germany
France
Holland
India
Italy
Japan
New Zealand
Norway
Sweden
Switzerland
United Kingdom
United States of America

5. To facilitate intercountry comparison, each country is given on a separate page, the 16 pages being arranged alphabetically as in the above list. The key to the aspects noted for each country (14 aspects in all) is given on the *foldout* page placed at the end of the 16 pages.

6. In view of the importance to the UK industry of any potential or draft EEC Directive becoming mandatory within EEC, the Annex III to the EEC 'Proposed General Directive on the Approximation of the Laws of the Member States concerning Pressure Vessels' is given below:

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11.537/III/IV/64–F
rev. IV

Annex III

Criteria to be taken into account by member states when approving organisations responsible for carrying out official individual inspection

1. The organisation, its director and the officials responsible for carrying out the inspection procedure may not be the constructor, the supplier nor the installer of the vessels or installations which they check, nor the agent for any of those parties. They may not be engaged in the marketing, representation or maintenance of those vessels or installations nor be agents for the parties engaged in such marketing, representation or maintenance.

2. The statutes of the organisation must include a clause excluding any commercial object.

3. The organisation must possess the equipment necessary for carrying out normal inspections of the type for which it is approved and be able to have access to the equipment necessary for unusual inspections.

4. The organisation must have competent and qualified senior staff who have a sound knowledge of the organisation's field of activity.

5. The officials responsible for checking must have:

(a) a satisfactory knowledge of the regulations concerning the checks they have to carry out and sufficient practice in those checks;

(b) the ability required to draw up the attestations and reports certifying the checks carried out.

6. The independence of personnel must be ensured by adequate guarantees of employment. Their remuneration must not be fixed in relation to the financial results of the organisation.

7. The organisation shall be responsible in civil law for prejudicial consequences arising from a defective inspection. This civil liability shall be covered by an insurance contract.

1. Australia

2. State inspection authorities

3. Individual State inspection authority (usually within State Departments of: Labour and Industry; or Mines; or the Interior)

4. All

5. Inspectors are employees of the States

6. No

7. The Factory and Machinery Acts of the various States, under which each State issues boiler and pressure vessel regulations

8. Standards Association of Australia Boiler Code, Parts I–V (Standard No. CB1)

9. BS: Lloyd's Rules; ASME Boiler Code

10. Boilers and Unfired pressure vessels

11. SAA Boiler Code has no legal status itself, but has been incorporated into the statutory requirements of some States, and thus has force of State Regulation in these States, and is accepted (with modifications) in the remainder

12. Standards Association of Australia

13. Vessels fabricated outside Australia (to other codes) may be accepted at the discretion of individual State Chief Inspectors

14. —

1. Austria
2. Inspection organisations authorised by a Government body
3. Government or TUV or other organisations
4. None
5. Subject to Government licence; also subject to special training and approval in the case of employment by other inspection organisations
6. Yes
7. Art 48 Verwaltungs-entlastungsgesetz (VEG) Bundesgesetzblatt No. 277/1925 as amended by BGBl No. 55/1948
8. Dampfkessel-Verordnung (DKV) BGBl No. 83/1948; Werkstoff und Bauvorschriften (WBV) BGBl No. 264/1949
9. Other codes may be accepted provided they are recognised as being equivalent
10. Boilers and Unfired pressure vessels
11. The codes are Ministerial Decrees and have the force of a state regulation
12. Bundesministerium für Handel und Wiederaufbau
13. Vessels must meet (at least) the requirements of the Austrian National Codes
14. —

1. **Belgium**

2. Independent inspection organisations authorised by Ministère de l'Emploi

3. AIB: Association Vincotte; and a number of other inspection organisations

4. The Inspection Division of the Ministère de l'Emploi et du Travail reserves the right to carry out a final inspection and witness the hydraulic test on user's site

5. Inspectors are subject to special training and approval by employing organisations

6. Yes

7. Le Règlement Général pour la Protection du Travail; and La Règlementation des Appareils à Vapeur. (These are royal decrees)

8. Titre IV of Le Règlement Général pour la Protection du Travail

9. Other recognised national codes are accepted provided they are equivalent in all respects

10. Boilers, steam vessels, pressurised gas containers

11. Force of law as Ministerial Decrees

12. In addition to the Decree; technical codes are published by Institute Belge de Normalisation and by the Association des Industriels de Belgique (AIB)

13. Pressure vessels built to major national codes are acceptable. Boilers must meet Belgium regulations (however drums may be treated as for pressure vessels in special cases)

14. —

1. **Canada**
2. Provincial Inspectorates; or independent organisations employing State-Certified Inspectors
3. Provincial Inspectorates or Engineering Insurance and other independent organisations
4. None
5. All inspectors are State Certified by Commission of the Canadian National Board of Inspectors
6. No—for Provincial Inspectorates;
   Yes—for independent inspection organisations
7. 'Boiler and Pressure Vessel Acts' of the various Provinces
8. CSA Standard B51–1960—'Code for Construction and Inspection of Boilers and Pressure Vessels'—this in turn refers to the ASME and ASA Standard B31.1 Codes regarding design
9. The degree to which the CSA Code must be followed varies from Province to Province
10. Boilers and Unfired pressure vessels
11. CSA–B51 Code has the force of a Provincial Regulation
12. CSA and ASME
13. Vessels must be inspected by a State Certified Inspector
14. —

1. France

2. Inspection organisations authorised by Government Body (but see 4 below)

3. APAVE (but see 4 below)—Association des Propriétaires d'Appareils à Vapeur et Electriques

4. The Direction des Mines of the Ministère de l'Industrie may reserve to itself the approval of drawings, the final inspection and the hydraulic test on user's site. This is normally delegated (eg to APAVE)

5. Inspectors employed by inspection organisations are subject to special training and approval by employers

6. Yes—against inspection organisations

7. Règlementation des Appareils à Vapeur (Modified Decree of 22.4.26 and Law of 28.10.43); and Règlementation des Appareils à Pression de Gaz (Modified Decree of 18.1.43 and Law of 28.10.43)

8. The regulations in 7 do not contain rules for the design of boilers and vessels. The only design code existing is that for unfired pressure vessels: SNCT No. 1 which has no direct legal recognition

9. See 13 below—Other codes are accepted if judged as providing equivalent levels of safety

10. Unfired pressure vessels only (in respect of design)

11. Force of law in respect of the Règlementations which constitute rules for the safety and for the official control of vessels (but these do not include requirements for vessel design)

12. SNCT (Syndicat National de Chaudronnerie et Tôlerie); however, the Règlementations are published by APAVE

13. Vessels must conform with French law and in particular Article 4 of the decree of 2.4.26 which specifies the tests and certificates required

14. —

1. **Federal Republic of Germany**

2. Inspection organisations authorised by Government (Ministry of Labour)

3. Technische Uberwachungs-Vereine (TUV) and others. Each 'Land' has its own Trade Supervisory Office which normally works through or recognises the TUV

4. None

5. Inspectors employed by inspection organisations are subject to special training and approval by employer

6. Yes

7. Various statutory ordnances of the Ministry of Labour of the Federal Government

8. Boilers—Technische Regeln für Dampfkessel (TRD)
   Pressure Vessels—AD-Merkblätter and Unfallverhutüngsvorschriften (UVV)

9. Other codes accepted if judged as equivalent by TUV

10. Boilers (TRD) and Pressure Vessels (UVV and AD-Merkblätter)

11. TRD, UVV and AD-M have force of law

12. Boilers—Deutscher Dampfkesselausschuss (DDA)
    Pressure Vessels—Arbeitsgemeinschaft Druckbehälter (AD) and UVV: Druckbehälter

13. Vessels must meet the German Code requirements and be inspected by TUV or approved inspection organisations

14. —

1. Holland

2. State Inspectorate

3. Dienst voor het Stoomwezen

4. Stoomwezen reserves the right to carry out a final inspection and hydraulic test at the maker's works in any country

5. All inspectors of Stoomwezen are State-employed

6. No

7. Stoomwet (general legal requirements); Stoombesluit of 22.12.53 for boilers; Outwerp Drukhouderbesluit of 15.3.60 for unfired pressure vessels

8. Grondslagen, Waarop de Beoordeling van de Constructie en het Material van Stoomtoestellen, Damptoestellen en Drukhoudersberust

9. None

10. Boilers and Unfired pressure vessels (as well as gas cylinders etc)

11. Force of law

12. Dienst voor het Stoomwezen

13. Imported vessels must meet the requirements of Stoomwezen, which normally means that the Grondeslagen must be followed

14. —

1. **India**

2. State Inspectorates

3. For boilers—Boiler Inspectorates under the Central Boilers Board
For pressure vessels—Factory Inspectorates under Chief Adviser of Factories (Ministry of Labour)

4. All (but see 13 below)

5. All inspectors are state-employed

6. No

7. For boilers—Indian Boilers Act, 1923
For pressure vessels—Indian Factories Act

8. For boilers—Indian Boiler Regulations, 1950
For pressure vessels—None

9. BS and ASME etc. are acceptable for boilers and pressure vessels

10. Boilers

11. For boilers, Regulations have force of law

12. For boilers; Central Boilers Board

13. For boilers, design must be pre-approved, and vessel inspection certificate approved, by Chief Inspector of Boilers (India) but inspection during manufacture may be delegated to approved inspection organisation

14. The Indian Standards Institution intends to establish an unfired pressure vessel code, but it would not have a mandatory status under the existing law

1. Italy

2. State Inspectorate

3. Associazione Nazionale per il Controllo della Combustione (ANCC)

4. Normally all inspection is carried out by ANCC: but this may be delegated by ANCC to other approved inspection organisations outside Italy. ANCC reserves the right to carry out final inspection and hydraulic test at the makers in any country

5. All inspectors of ANCC are State-employed

6. No

7. Various royal and governmental decrees dating from 9·9·26

8. Controllo della Combustione Apparecchi a Pressione (1964) No. ANCC N775; Specifiche per la Construziore Saldata di Apparecchi a Pressione Soggetti al Controllo dell' ANCC

9. None

10. Boilers and Unfired pressure vessels

11. The ANCC Codes have force of law

12. ANCC (codes are generally in line with Italian Standards Institute)

13. Imported vessels must meet ANCC requirements

14. Gas cylinders etc. come under the Italian Ministry of Transport (Ispettorato Motorizzazione Civile—the IGMC)

1. **Japan**
2. State Inspectorates
3. Labour Standards Bureaux (Ministry of Labour); Labour Standards Offices and Labour Standard Inspection Offices in each Prefecture
4. Most (for maintenance inspection authorised inspection organisations may be used)
5. Inspectors are employed by the Prefectural Governments
6. No
7. The Regulation for Safety of Boilers and Pressure Vessels (a Ministry of Labour Ordinance)
8. Ministry of Labour Notices: Boiler Construction Code,
   Pressure Vessel Construction Code
9. Whilst other codes are not officially recognised, vessels so constructed are generally acceptable if the other codes are more stringent than the corresponding Japanese one
10. Boilers and pressure vessels
11. Inspection of plate material, welds and the acceptance inspection of the completed vessel are legal requirements
    The Codes have force of law
12. The Japanese Industrial Standards Committee (JIS) prepares specifications and codes of practice, these have no legal standing in themselves, but are used in practice
13. Unless 9 above is complied with, supplementary tests may be called for by the Japanese authorities
14. Boilers and nuclear containers used in electricity generation, and high-pressure gas containers, come under the Ministry of International Trade and Industry; while marine boilers and pressure vessels come under the Ministry of Transport

1. New Zealand

2. State inspection body

3. Marine Department, New Zealand

4. None, although final inspection prior to certification and use is made by Engineer Surveyors of Marine Department

5. All inspectors are State-employed

6. No

7. Boilers, Lifts and Cranes Act, 1960

8. New Zealand Boiler Code
New Zealand Fusion Welded Pressure Vessel Code

9. —

10. Boilers and Unfired pressure vessels

11. Force of law

12. Marine Department, New Zealand

13. Design and final inspection normally required for approval by Marine Department; although fabrication inspection may be by authorised inspection organisations

14. —

1. **Norway**

2. State inspection body (but can authorise independent inspection organisations)

3. Arbeidstilsynets Kjelkontroll

4. Inspection during fabrication and the hydraulic test may be carried out by authorised inspection organisations

5. All inspectors are State-employed

6. No

7. Worker's Protection Act, 1956

8. Forskrifter for Kjeler, beholdere og Rørledninger som er Utsatt for Damp trykk (1967)

9. Tryckkarlsnormer (Swedish); INSTA Recommendation on Welding (Scandinavian); (BS, TUV, and ASME Codes are also acceptable provided designed vessel is equal to or superior to that of the Forskrifter)

10. Boilers and pressure vessels

11. Force of law

12. Arbeidstilsynets Kjelkontroll, in co-operation with technical committee appointed by the Ministry of Labour

13. Imported vessels must be acceptable to Kjelkontroll

14. —

1. Sweden

2. Inspection organisations authorised by National Swedish Board of Industrial Safety

3. Angpanneforeningen (Swedish Steam Users Association),
   Tekniska Rontgencentralen AB (Technical X-Ray Centre)

4. Normally final inspection is by one of the bodies in 3 above, but in special cases other inspection organisations may be authorised to carry this out

5. Inspectors employed by authorised organisations are subject to special training and approval by employers

6. Yes

7. Labour Welfare Act
   Arbetarskyddslagen: Svensk Forfattningssamling No. 1/1949 (Law for the Protection of Workers) and Arbetarskyddskungorelsen: Svensk Forfattningssamling No. 476/1956 (Notice for the Protection of Workers)
8. Boilers—Angpannenormer,
   Pressure Vessels—Tryckkarlsnormer,
   Welding of Pressure Vessels—Pannsvetnormer, and other codes

9. None

10. Various codes cover most types of pressure container

11. National Codes have no direct legal status, but are approved by the National Swedish Board of Industrial Safety and have in effect the force of law

12. Pressure Vessel Commission (Royal Swedish Academy of Engineering Sciences) and Welding Commission

13. Vessels must meet the requirements of the Swedish Codes

14. —

1. **Switzerland**

2. Inspection Organisations authorised by a Federal Body

3. Swiss Association of Boiler Proprietors

4. None

5. Inspectors are subject to special training and approval by the employing body

6. Yes

7. Federal Regulations of 9.4.25 and 19.3.38

8. Regulations of Swiss Association of Boiler Proprietors

9. None

10. Boilers and Unfired pressure vessels

11. The Regulations have the force of law

12. Swiss Association of Boiler Proprietors

13. Vessels manufactured outside Switzerland must conform to Swiss Regulations, but inspection by authorised inspection organisations acceptable

14. —

1. **United Kingdom**

2. Independent inspection organisations

3. AOTC, Lloyd's Register, various engineering insurance companies (members of BIA etc.), large users

4. None

5. No national certification of inspectors; but those employed by insurance and/or inspection organisations are subject to special training and approval by employing organisation

6. Yes

7. Factories Act, 1961 (Sections 32–39) deals with boilers and certain other classes of pressure vessel, but does not specifically include unfired pressure vessels (as used in process plant for example)

8. BS1113, 1500, 1515 etc.

9. Rules of the AOTC; Lloyd's Rules; ASME Section VIII; or any approved code of design and practice

10. Boilers and Unfired pressure vessels

11. Not legally mandatory. Safety is the responsibility of the user who must ensure that steam boilers are of 'good construction, sound material, adequate strength, and free from patent defect' (Sections 32–39, Factories Act). Use of BS or other recognised codes could provide aid to legal defence
12. BSI

13. There are no technical regulations as to the acceptability of imported vessels (although Factories Act does apply in respect of their use)

14. Other classes of pressure container come under different Acts and Government Departments (eg gas cylinders come under the Home Office)

UNITED STATES OF AMERICA

1. **United States of America**	1. **Country**
2. State Inspectorates, or independent organisations employing State-Certified Inspectors	2. Status of Inspection Organisation(s)
3. State Inspection Authorities or Engineering Insurance Companies	3. Inspection Organisation(s)
4. None	4. Inspections that may be retained under control of a Government Department
5. All inspectors are certified by the National Board of Boiler and Pressure Vessel Inspectors	5. Certification of Individual Inspectors
6. No—for State Inspectorates, Yes—for independent inspection organisations	6. May Court action be taken against the Inspection organisation(s) in the case of negligence
7. Various State and Municipal Regulations	7. Laws relating to the construction and/or use of boilers and pressure vessels
8. ASME Codes	8. National Code(s) for design and construction
9. None	9. Other Codes permitted for national use
10. Boilers and Unfired pressure vessels	10. Scope of Code (Vessel types)
11. Varies from State to State, but most States have adopted the ASME Codes and these have force of law	11. Legal Standing of National Code
12. ASME	12. National Code Preparing Body
13. Imported vessels are subject to approval by separate State authorities and are normally acceptable if they conform to the ASME Codes	13. Acceptability of imported vessels
14. —	14. Other comment

APPENDIX Q

Review of response towards idealised model for a national inspection authority (NIA)

Comments on inspection in replies to general enquiry letter of 2/2/67

1. Inspection of pressure vessels was one of the most frequently raised topics in replies to the General Enquiry Letter circulated in February 1967 (see Appendix E). A substantial number of organisations identified unsatisfactory inspection procedures as a cause for delay in the fabrication and completion of pressure vessels, which in turn detracted from the competitiveness of the industry, for example through delays and imposition of additional administrative overheads.

2. Unnecessary multiplicity of inspection (whereby different inspection organisations had different inspection procedures and standards and appeared unwilling to accept each others standards and methods) was noted in 28 replies. Alternatives to the present procedures were suggested, for example the approval of the fabricators' own inspectors along the lines of AID approval. In five other replies the licensing of fabricators' own inspectors to carry out the stage inspections was suggested, similar to certain procedures abroad. Several proposed that the national certification of pressure vessel inspectors be initiated in the form of a professional register, with the aim of encouraging common standards of inspection throughout the country, particularly in view of the increasing use of ultrasonic and other testing techniques.

3. Three replies urged rationalisation of inspection at the international level. Respondents believed the acceptance of UK inspection by foreign customers would be facilitated were the UK to have a semi-official or national inspection organisation. In considering these modifications six respondents believed the requirements of the customer should be fully recognised.

Proposal for a National Inspection Authority

4. In view of the widespread comments on inspection, and the wide variety of problems involved in inspection with its associated variety of potential solutions, the Committee of Enquiry's Sub-committee on Inspection prepared an idealised model for a single UK inspection organisation. This model attempted to cover, in an idealised and simplified form, many of the points raised in earlier replies to the General Enquiry Letter.

5. The idealised inspection procedure for the fabrication of pressure vessels was proposed in the form of a single National Inspection Authority (NIA) directly responsible to the Minister of Technology and employing its own inspectors. The activities of NIA included the inspection of design, materials and fabrication of pressure vessels up to and including the commissioning or pressure test, but excluded the routine or maintenance inspection of pressure vessels or boilers once these were in service.

6. A letter with 'Recommendations on Inspection and Insurance by a Sub-committee of the Minister of Technology's Committee of Enquiry on Pressure Vessels' was circulated in July 1967 to 19 organisations for comment. Several of the organisations sought further views from associated or other organisations, and altogether replies were received from 28 organisations in the following groups:

Government departments	3
Public bodies (*or* government aided bodies)	4
Professional institutions	0
Trades and professional unions	3
Industrial and trade organisations and independent organisations for:	
Materials supply	3
Manufacturing	6
Inspection	3
Consultants and users	6
TOTAL	28

Analysis of replies to proposals for a NIA

7. Implicit in the Recommendations of the Sub-committee for the creation of a NIA were the following propositions; together with an alternative (d) not mentioned in these propositions but put forward in replies to the proposals:

(a) The concept of co-ordinated inspection (through the desire to reduce certain multiplicity of inspection at steel mills and at fabricators' works);

(b) The creation of a single inspection authority;

(c) The creation of a National Inspection Authority (NIA) under the Minister of Technology and employing its own inspectors;

(d) The creation of a single authority with delegated powers to approve certain inspection organisations (put forward in replies to the proposals);

(e) The certification of fabricators to inspect their own products (similar to the DGI or AID approved inspection system);

(f) The creation of a Case Law Committee;

(g) The preparation of design and inspection criteria;

(h) The institution of formal state or nationally-approved certification of inspectors.

8. An analysis of the replies is given below, in which the replies for each proposition have been summed and expressed as percentages relative to the total number of replies (which is 28):

Proposal	*Accept*	*Reject*	*Not mentioned/ neutral*
(a)	86%	7%	7%
(b)	54%	32%	14%
(c)	14%	82%	4%
(d)	32%	4%	64%
(e)	57%	0	43%
(f)	29%	14%	57%
(g)	57%	0	43%
(h)	36%	7%	57%

9. From the above analysis the following broad conclusions resulted from the replies to the proposals on the NIA.

(a) There was almost unanimous support for the need to co-ordinate inspection in the UK, so as to minimise multiplicity. The problems of multiplicity could arise from a double interest in inspection through:

the desire of two or more parties to see the same thing on different occasions, or
the desire of two or more parties to see different things done (ie inspection to different standards).

The parties involved included:

the steel supplier and fabricator, who should ensure their products conformed to the specifications,
the user or customer, who needed to be satisfied (by his own or by an independent organisation) that the product conformed to the specification,
the insurer, who needed confirmation that the vessel was built to an acceptable minimum standard.

In supporting the need for co-ordination five respondents concurred with reported resistance to change by the insurance companies, but nine respondents did not entirely accept this and several also considered that insurance companies had provided a helpful service. It was noted by several respondents that some multiplicity appeared inevitable in the present fabrication industry, which had 'within it over two hundred companies'.

(b) There was nett support (but with substantial opposition) for the creation of a single independent inspection authority.

(c) There was almost unanimous rejection of the proposed NIA employing its own inspectors. Major criticisms of the proposed NIA were that it would be in a monopolistic position (5 replies) whilst its possible bureaucratic rigidity and slowness (5 other replies) could render its service less efficient than that under free competition. Seven respondents queried how the NIA would be financed, what fees it would charge and whether it would be subject to Treasury in terms of staff complement.

(d) There was a measure of support (with negligible opposition) towards the creation of a single authority with delegated powers to approve certain inspection bodies. Several respondents saw such an authority as being similar to the British Calibration Service and could be linked to the proposed 'National Authentication Service' with powers:

to ensure exact common standards of inspection that would be acceptable internationally,

to certify the competence of any inspection body, whether that of the user, the insurer, the inspector, or the manufacturer, and

to ensure that unnecessary duplication of inspection be avoided.

Furthermore, certified inspection organisations should continue to: be responsible for progressing work to ensure delivery dates were met; be available for employment on overseas contracts; to act as a means of exchanging information and experience between the user and the manufacturer.

(e) There was considerable support (with no opposition) for certification of fabricators to inspect their own products. Indeed one respondent considered it would be practicable to introduce this now, particularly in view of the undoubted success of such schemes as operated by AID, EID and ARB, although another respondent was unaware of any users that had accepted fabricators' certificates as entirely satisfying users' needs. Six respondents felt that whilst stage inspection should be the responsibility of the fabricator, there should be checks by independent organisations particularly on completed vessels.

(f) There was some nett support (with opposition) for the creation of a Case Law Committee where this was defined as providing interpretations and rulings in respect of individual cases put before it. One respondent felt that concessions made by the Case Law Committee (under an AID type of procedure) should involve the concurrence of the customer's design department (as was the practice with AID). However, another respondent felt that if the concurrance of the customer were necessary, the whole objective of using the procedure might be negated. Several respondents queried who would be final arbiter in disputes, and what provisions would be made for appeals.

(g) There was considerable support (with no opposition) towards the preparation of both technical design standards and inspection standards, and several respondents wished to see a unified or common standards document for steelmaker, fabricator and inspection authority which would be presented in one comprehensive document. Several respondents (22%) went further and indicated that they would wish to see the preparation of these standards associated with BSI in some way.

(h) There was nett support (with little opposition) for nationally-approved certification of inspectors. An alternative procedure was suggested, which was really equivalent to (d), whereby the inspection organisations should be certified rather than the inspectors. It was also suggested that national certificates in NDT and in radiography be awarded. These certificates should be at a comparable level with those in other countries abroad. A nationally recognised training and re-education scheme should be initiated. It would also be desirable to define what was meant by a 'competent person' in terms of the Factory Acts, and a nationally recognised certification scheme would permit this.

Analysis of other aspects raised in the replies

10. Nine respondents queried what the scope of the proposed NIA would be in terms of pressure vessel type; while four made the point that the proposed use of the vessel should also be taken into account during inspection. Others queried the relationship between the NIA in pre-commissioning inspection and the Factory Inspectorate in post-commissioning inspection. Four of the replies inquired as to the policy of NIA in respect of safety. Several raised queries on what degree of contractual protection would arise through use of the NIA, ie performance guarantees arising from inadequate inspection, consequential damages, indemnification of manufacturer/contractor, etc.

11. Several respondents considered that advances in technology should be reflected continuously in NIA, and that a further Committee should be set up to co-ordinate the national R & D programme on pressure vessels.

12. Fourteen respondents rejected the suggestion made by the Sub-committee that foreign inspection authorities might be less thorough and detailed than those in the UK. Thus: 'evidence as to the unfair position of UK fabricators in relation to overseas orders would have to show that the overseas purchasers (or their agents) were themselves adopting different standards of acceptance in any particular contract, according to whether construction took place in the UK or elsewhere'. Five respondents took

some UK fabricators to task for a certain lack of internal organisation and poor control of their production. Further criticism was made of some UK fabricators for not keeping (in contra-distinction to fabricators abroad) adequate records and documentation relating to pressure vessels covering materials used, plant manufactured, certificates issued, etc.

13. Some confusion was caused by inclusion of the word 'insurance' in the title of the Sub-committee's report. Nine replies asked why insurance had been included since pre-commissioning inspection taken on behalf of the customer or post-commissioning inspection made on behalf of Factory Inspectorate were independent of the insurance of the plant concerned.

14. Twelve respondents queried whether the full legal implications had been considered for a body such as the proposed NIA. One respondent sought for co-ordination of the statutory requirements relating to 'pressure equipment', as boilers must conform to DEP regulations, boiler explosions reported to and assessed by Board of Trade, gas cylinders must conform to Home Office regulations, and if an NIA as proposed by the Sub-committee came about then pressure vessels would have to conform to Ministry of Technology regulations.

APPENDIX R

Legislation relating to pressure vessels and their use

1. This appendix summarises the UK legislation as at 1968, comments on proposed alterations, and briefly surveys the statutory position abroad. It should be noted that there is no legal requirement in the UK to provide insurance cover for pressure vessels either as such or as an integral part of a plant, and insurance (in contradistinction to safety) is a commercial arrangement quite distinct from either technical considerations or statutory requirements. (This does not necessarily apply in all other countries, eg, in Canada the owner or user may operate a steam boiler provided it is insured with some Boiler Insurance Company, registered in the Department of Insurance or has been inspected and reported safe by an authorised person within the calendar year).

Present UK legislation

2. The principal statutory requirements are contained in or regulated by: the Factories Act 1961, the Mines and Quarries Act 1954, the Petroleum Consolidation Act 1928, the Gas Cylinders (Conveyance) Regulations 1931 (amended in 1947 and 1959), and the Boiler Explosion Acts of 1882 and 1890. The Nuclear Inspectorate of the Ministry of Power embodies its requirements in the site licence for Nuclear Power Stations. The only local authority requirement is imposed by Greater London Council which has bye-laws for inspection of boilers, pressure vessels and similar plant in use in places of entertainment etc. There are no standard or mandatory requirements by UK professional institutions, Trade Associations, independent inspection organisations, or insurance underwriters. A wide variety of Government departments are therefore responsible for various aspects of legislation relating to pressure vessels and boilers, including: Department of Employment and Productivity, Home Office, Board of Trade, Ministry of Power (Inspectorate of Nuclear Installations) and Ministry of Transport.

3. The Boiler Explosions Acts in general apply to pressure vessels with which heat is associated. The Factories Act applies to certain classes of pressure vessels such as Boilers, Steam and Air Receivers, etc., installed in factories. Both Acts impose a statutory duty on the competent person who has issued a report, and in the event of his being found negligent he may suffer severe legal penalties, which may also be incurred by other members of the inspection organisation concerned.

The Factories Act 1961

4. The Factories Act 1961 is administered by the DEP and is concerned with the following types of equipment:

(a) Steam Boilers—defined in Section 38 of the Act as any closed vessel in which for any purpose steam is generated under pressure greater than atmospheric pressure and including any economiser used to heat water being fed to any such vessel, and any superheater used for heating steam.

(b) Steam Receivers—defined in Section 35 of the Act as any vessel or apparatus (other than a steam boiler, steam container, a steam pipe or coil, or a part of a prime mover) used for containing steam under pressure greater than atmospheric pressure.

(c) Steam Containers—defined in Section 35 as any vessel (other than a steam pipe or coil) constructed with a permanent outlet into the atmosphere or into a space where the pressure does not exceed atmospheric pressure, and through which steam is passed at atmospheric pressure or at approximately that pressure for the purpose of heating, boiling, drying, evaporating or other similar purpose.

(d) Air Receivers—defined in Section 36(6) as:

(i) any vessel (other than a pipe or coil, or an accessory, fitting or part of a compressor) for containing compressed air and connected with an air compressing plant; or

(ii) any fixed vessel for containing compressed air or compressed exhaust gases and used for the purpose of starting an internal combustion engine; or

(iii) any fixed or portable vessel (not being part of a spraying pistol) used for the purpose of spraying by means of compressed air, any paint, varnish, lacquer or similar material; or

(iv) any vessel in which oil is stored and from which it is forced by compressed air.

5. Basically the Factories Act and Regulations are intended to ensure that vessels are properly designed and constructed, correctly maintained in service, and are fitted with the essential devices to ensure safety. The standards laid down in the Act are minimum standards, and in practice, higher standards are often found.

6. The Act does not give detailed methods of construction, design criteria or acceptable methods of manufacture. The meaning of 'good construction, sound material and adequate strength' can only be interpreted in the final event by a court of law, but from an administrative point of view, British Standards are, when applicable, used as the yardstick.

7. The Act defines requirements governing the method of examination and the periods between examinations. It also requires examination by a 'competent person'. This phrase is not defined in the Act but the interpretation generally applied by the Factory Inspectorate is: 'a competent person is a person with such practical and theoretical knowledge and experience of the plant he has to examine as will enable him to detect defects or weaknesses and to assess their importance in relation to the strength and function of the plant in question'. In the main, examinations are carried out by Surveyors of Insurance Companies, Lloyd's Register and other specialised bodies. Under Section 33(4) the report of the examination of a steam boiler must be signed by the person making the examination and if that person is an inspector of a boiler-inspecting company or association, be countersigned by the chief engineer of the company or association. Furthermore, under Section 33(8), if the Chief Inspector of Factories is not satisfied as to the competency of the person employed to make the examination or as to the thoroughness of the examination, he may require the boiler to be re-examined by a person nominated by him and if it is established that the report of the previous examination was inadequate or inaccurate in any material particular, the cost of the re-examination may be recovered from the occupier of the factory.

8. *It is important to note* that a wide range of pressure vessels do not come under the requirements of the 1961 Act. There are also no statutory requirements covering the pre-commissioning area which is contrarary to the situation in some foreign countries.

The Mines and Quarries Act 1961

9. The Mines and Quarries Act is administered by the Ministry of Power and requires under Section 84 that 'all apparatus used as, or forming, part of the equipment of a mine, being apparatus which contains or produces air, gas or steam at a pressure greater than atmospheric pressure shall be so constructed, installed, maintained and used as to obviate any risk from fire, bursting, explosion or collapse or the production of noxious gases'.

The Petroleum Consolidation Act 1928

10. The conveyance of gas cylinders by road in the UK is controlled in respect of cylinders containing the permanent gases of air, argon, carbon monoxide, coal gas, hydrogen, methane, neon, nitrogen, and oxygen. The main instrument of control is the Gas Cylinders (Conveyance) Regulations 1931, amended in 1947 and 1959, which lays down in considerable detail specifications for materials, design, construction and testing of cylinders. The bulk of these specifications are embodied in British Standards which are restated in the schedules to the Order but it should be noted that:

(a) The British Standards embody specifications drawn up, in consultation with other interests, by the Home Office and are not the usual product of consensus machinery operating through BSI's technical committee structure;

(b) Some detailed parameters or design considerations involve so much uncertainty or depend so much on accumulated experience that they cannot be defined for the purposes of a British or international standard and must be left to the discretion of the Home Office, which receives technical advice from the National Testing Laboratories, particularly the National Engineering Laboratory.

In addition, the storage and conveyance of dissolved acetylene in cylinders containing a homogeneous porous mass is subject to the requirements of Order of Secretary of State No. 9 made under the Explosives Act 1875.

11. At present cylinders which do not comply with the Regulations are not controlled under the Order except in the case of cylinders complying with Exemption Order No. 16 and the latter type of cylinder is the only cylinder for which an approval procedure is legally required. This involves very close supervision of prototype testing and approval, as well as quality control of production under the supervision of approved bodies which include Lloyds, the AOTC, the British Oxygen Co., ICI and a number of similar agencies overseas. The designation of overseas agencies as approved for the purpose of the Home Office requirements enables foreign manufacturers to design and produce such cylinders to UK requirements. The following cylinders are allowed to be used for the conveyance of gases named in the Regulations on a 'no objection' basis pending the review of the Regulations:

(a) Alloy steel cylinders to Home Office specifications S and T;

(b) Aluminium alloy cylinders to HO Specifications HOAL 1 and HOAL 2.

12. The present position regarding the approval of gas cylinders in the UK is as follows. The Home Office is responsible for the legislation relating to the carriage of gas cylinders on roads in the UK. This does not cover factory sites which come under the Factory Acts (DEP), but every gas cylinder to which the Gas Cylinders (Conveyance) Regulations apply must comply with these regulations because all gas cylinders are, at one time or another, transported by road. The Factory Inspectorate in its turn normally wishes to see Home Office regulations followed on factory sites. British Railways, although covered by different legislation do follow, as far as transportable gas cylinders are concerned, the Home Office regulations.

13. The Home Office has an arrangement with BSI, whereby the BSI print and publish the technical design and inspection requirements for gas cylinders as a BS, but where appropriate it is noted in the BS that the BS are, in fact, mandatory and that gas cylinders may only be manufactured and inspected by manufacturers and independent inspection organisations approved by the Minister of State, Home Office.

14. The procedure for approval where appropriate is as follows. A manufacturer that wishes to start production of gas cylinders must apply to the Home Office for permission to do so. The Home Office seeks views on the performance, quality, reliability and other aspects of the manufacturer from other bodies (users, inspection bodies, government departments etc.). Provided no cause for uncertainty arises as a result of the views received, the second stage is entered whereby the manufacturer submits designs of the entire range of gas cylinders he proposes to make and details of the manufacturing process. If, on the examination of this information, it appears probable that the applicant is capable of making the types of cylinders concerned, the Home Office decides which sizes the manufacturer shall make for the purposes of the initial acceptance test. Normally 20 gas cylinders of each size are required to be made and a random sample of six selected by an approved inspection organisation for further test by the National Laboratories. If the gas cylinder is very large (say 30 inches in diameter) then special provision is given for only one to be made. This single cylinder must, however, be made under the surveillance of the approved inspection organisation to ensure that the manufacturer's normal control procedures are used and that no special treatment is afforded the one test cylinder. For large cylinders the inspecting authority will carry out a hydraulic stretch test in which the permanent stretch of the cylinder after the prescribed pressure test is measured as a proportion of the total expansion of the cylinder under the test pressure. For steel cylinders this proportion must not exceed 10% but is normally less than 1%; for aluminium alloy cylinders no permanent stretch is permitted. After this test sections of a large cylinder will be subjected to further tests (notch, bend, tension, metallurgical, etc.) by the National Laboratories on behalf of the Home Office. In the case of normal commercial size cylinders, the sample cylinders will be sent complete for all the required testing to be done by these Laboratories. Provided the manufacturer passes all these tests then the Home Office sends a *letter* to the manufacturer (ie not a certificate) stating that he has been approved to manufacture gas cylinders of certain types (ie those types and sizes for which the manufacturer has been specifically tested and no other). Should the manufacturer wish to make larger and/or different gas cylinders to those for which he is already approved, he has to seek new Home Office approval in the usual way.

15. The procedure for approval of inspection organisations follows a similar pattern. The Home Office seeks advice on an inspection organisation's capabilities by consulting other organisations including other inspection bodies, also users and manufacturers that have already been inspected (for other products) by the inspection organisation seeking approval.

16. The Home Office keeps a Register of Approved Manufacturers and a Register of Approved Inspection Organisations. Only those on the Registers may legally practice in the manufacture and inspection of certain gas cylinders.

17. The Home Office Regulations cover both approval and certification of each gas cylinder as it is made, as well as the re-certification of every gas cylinder (by an approved inspection organisation or by an approved manufacturer with an approved inspection department) at least every 5 years.

18. It may therefore be seen that the Home Office Regulations cover both manufacturing inspection as well as maintenance inspection. The Home Office also acts as the equivalent of a 'Pressure Vessel Authority' in that it 'approves' inspection organisations and draws up the technical specifications and inspection procedures to be used, at least in the field of gas cylinders (transportable).

The Boiler Explosion Acts of 1882 *and* 1890

19. The Boiler Explosion Acts 1882 and 1890 are administered by the Board of Trade and provide for inquiries to be held with respect to explosions from boilers in the United Kingdom and in British Ships. The owner of any boiler (subject to certain exceptions) from which an explosion occurs must report the fact to the Board of Trade, which thereupon arranges for an engineer surveyor to inquire into the cause of the explosion. The reports of minor explosions are not published, but the cause of the explosion as ascertained by the Board's surveyors, together with the Engineer Surveyor-in-Chief's comments are communicated to the owner and to the Factory Inspectorate.

20. Any available information about a boiler explosion obtainable at the time or shortly after is also sent by the District Inspector to the Engineering Branch of the Inspectorate and an Engineering Inspector may make a visit to obtain first-hand information on the occurrence, but the official investigation as to the cause of the explosion remains the responsibility of the Board of Trade. It should be noted that the Board of Trade have no duties, or indeed powers, to ensure that any recommendations made by them are implemented by the occupier. In practice, copies of their Surveyor's reports are forwarded to the Chief Inspector of Factories, and these are referred to the appropriate District Inspector, who takes any necessary action.

21. The definition of a boiler in the Acts includes any closed vessel used for heating water as well as *other liquids.*

Proposed alterations to legislation

22. Alterations are proposed to both the Factories Act 1961 and the Petroleum Consolidation Act 1928.

Factories Act

23. A First Consultative Document was circulated by the DEP in 1967 outlining a proposed revision of the Factories Act 1961. Whereas the 1961 Act omitted a wide range of pressure vessels the proposed revisions are designed to cover the whole of the pressure vessel field.

24. It is the intention to include in the Bill definitions of 'steam boiler', 'hot water boiler', 'pressure vessel' and 'gas holder'.

25. 'Steam boiler' will include any vessel in which steam is generated under pressure greater than atmospheric pressure. It will be made clear by the definition that when either a superheater or an economiser is an integral part of a steam boiler then it and the steam boiler will be treated as one vessel for the purposes of requirements under the Bill or Regulations, but that when a superheater or economiser is a separate vessel and heated by a separate source of heat, it will be regarded as an individual pressure vessel and will be required to conform with the requirements of the Bill or any regulations made thereunder.

26. 'Hot water boiler' will be defined as meaning any vessel in which water is heated to a temperature greater than 110°C. and in which steam is not intentionally generated.

27. It will be made clear that the definitions in paragraphs 25 and 26 above do not apply to any vessel used for the purposes of a chemical reaction.

28. 'Pressure vessel' will be defined as meaning any vessel used to contain steam, air or any liquefied or compressed gas or fumes at a pressure greater than atmospheric pressure. It will, however, be made clear that this definition does not include:

(a) a gas holder as defined below;

(b) a pipe or coil;

(c) any part of a prime mover;

(d) any vessel forming part of a portable tool;

(e) solid drawn gas bottles or cylinders used for the storage and supply of compressed air or compressed and liquefied gases.

29. 'Gas holder' will be defined in terms which will include any water-sealed gas holder, water-less gas holder, dry-scaled gas holder, or flexible gas storage container, together with its immediate ancillary plant, apparatus and parts which enables the gas holder to function as such and in which the pressure of gas in the holder does not exceed 70 centimetres water gauge.

30. The Minister will be given the power by regulations to extend the definitions in the preceding paragraphs to any other device.

31. There will be a general requirement that every steam boiler, hot water boiler, pressure vessel, still and gas holder, together with all the fittings and attachments necessary to the safe operation of the same shall be of good construction and design, sound material and adequate strength for the purpose for which it is used and shall be properly maintained.

32. There will follow a provision requiring every steam boiler, hot water boiler, pressure vessel, still and gas holder to have fitted and attached to it such fittings and attachments as may be prescribed by the Minister by regulations.

33. The Minister will be empowered to make regulations about the testing and examination of steam boilers, hot water boilers, pressure vessels, stills and gas holders.

This regulation-making power will be wide enough to enable the Minister to regulate what is to be examined, how it is to be examined, how frequently it is to be examined, the keeping of records of such examinations and the form and availability of such records and to make stipulations and requirements as to who shall undertake the examinations.

34. In particular, the Minister will be empowered to make regulations providing that steam boilers, hot water boilers, pressure vessels, stills and gas holders shall not be used in any premises or operations unless they have been tested and examined, together with their fittings and attachments in such a manner as the Minister may by regulations prescribe.

35. It is the intention that before this part of the Bill is brought into force regulations will be made under paragraphs 32 – 34 above covering the matters at present contained in Sections 32, 33, 35, 36 and 39 of the Factories Act 1961 and the requirements of such regulations will not be less than those of the sections just mentioned.

36. The Minister will be given power to prescribe by regulations that, in certain cases, tests and examinations should be undertaken by competent persons and the Minister will be given power to approve such competent persons or to withdraw his approval of such persons if he thinks this necessary. Such persons will be given a right of appeal against a decision of the Minister.

37. The Minister will also be given power by regulations to impose requirements with respect to the design, construction, installation, examination, repair, maintenance, alteration, adjustment and testing of pressure vessels and *this power will be wide enough to enable the Minister where he considers it appropriate to require compliance with provisions laid down by a body authorised by him for the purpose.*

Petroleum Consolidation Act 1928

38. The Home Office in 1946 set up a Departmental Committee with the task of reviewing the legislation on gas cylinders originally passed by Parliament in 1931. Up to 1960 the Committee had acted purely departmentally in that a draft report had been prepared based on the department's own experience and requirements in respect of the 'safety of the public at large during the transmission or transport of gas cylinders on public roads'. In 1960 the Home Office circulated 500 copies of the draft report to other departments and to industry. Such a large quantity of constructive criticism was received by the Home Office that it was decided to restart ab-initio, and BSI were invited to nominate eight representatives from industry to participate in the activities of the Committee.

39. The Committee has now completed its task and its report will be published in due course.

40. It is understood that the report contains a wealth of technical specifications which will be redrafted by a series of BSI Committees into a number of BS for gas cylinders of various types; the BS to be promulgated will be mandatory under the new legislation.

41. The Report will recommend that the Home Office Regulations, and approvals procedure, be extended in breadth to cover not only conventional transportable gas

cylinders, but also *all* pressure containers carried on the roads. This would include all high-pressure gas transporters etc. Other fundamental changes in the present system of control are, for example, the instituting of approval for material manufacturers and the extending of the range of gases covered, both permanent and liquefiable. It will cover also welded gas cylinders as well as the seamless type which are at present the only ones covered by the Regulations.

42. The report will also recommend that consideration should be given to the acceptance in the UK of cylinders made to foreign specifications subject to those specifications being examined and found satisfactory.

Foreign legislation

43. The UK at present is the only major industrial country which does not insist on a national standard for construction for pressure vessels. Provided the competent certifying authority considers that a vessel is safe to work between specified examinations it may be constructed to any design standard. The following details are given of statutory requirements in some of the major European industrial countries. Furthermore, standard requirements in many foreign countries differ from those in the UK in that certain other countries insist on some degree at least of *pre-commissioning* inspection during fabrication. The latter is not mandatory in the case of new vessels for installation in the UK.

Federal Republic of Germany

44. Inspection and approval of design is compulsory by law in respect of boilers, fired and unfired pressure vessels, calorifiers, autoclaves, air receivers, gas containers under pressure and transportable gas and liquid containers. The TUV is the official independent approval body responsible for the inspection and approval of all boilers and pressure vessels manufactured in and imported into Germany. TUV have an agreement with AOTC to inspect and approve boilers and pressure vessels in the UK before export to Germany.

45. The procedure required is briefly listed below:

(a) *Design.* The design has to be in accordance with the appropriate specifications.

(b) *Drawings.* Triplicate copies of the drawings are required which show all dimensions in metric units, design and hydraulic test pressures in kg/cm^2 (atmospheres) and design temperatures in degrees Centigrade. A parts identification list, giving the part number, quantity, description and type of material, is also required. The drawings should also indicate the design standard, the type of weld electrode and the method of welding.

(c) *Materials.* Materials are to be supplied by an approved manufacturer and should satisfy fully the requirements of the AD Data sheets, Series W for pressure vessels, and TRD sheets Series 101–110 for boilers.

(d) *Approval of works and welders.* Approval of works and welders is carried out by AOTC, British Engine Boiler & Electrical Insurance Co. Ltd. This approval work includes the inspection of works facilities and equipment, and testing to approve the works welding equipment. The works welders are also to be approved in accordance with the requirements of the appropriate design standard given in the Schedule.

(e) *Fabrication.* Fabrication has to be carried out in accordance with the recommended practices laid down in the relevant German design standards. The interim inspections during construction, the final interior inspection and hydraulic tests are normally carried out by AOTC under the authority of TUV, Essen. However, in the case of equipment such as gas cylinders and large transportable containers for liquid gases, all inspections are generally carried out by TUV.

46. There is no system of continuing approval; each item to be approved must be individually submitted.

France

47. Inspection and approval is compulsory by law and design, fabrication and inspection procedures are specified in Government regulations. The Ministère de l'Industrie (Direction des Mines) is the Government organisation for the inspection and approval of all boilers and pressure vessels imported into France. Interim inspections may be carried out by an approved body in the UK acceptable to the French Authorities, but the hydraulic test must be carried out in France by the Service des Mines.

48. The procedure required is as follows:

(a) *Design.* One copy of the calculations has to be forwarded to the Direction des Mines.
(b) *Drawings.* One copy of the design drawing is required. All measurements have to be shown in metric units, the design and hydraulic test pressures in bars and the design temperatures in degrees Centigrade. A parts identification list giving the part number, quantity, description and type of material has to be shown on the drawing.

(c) *Materials.* To be approved by the Service des Mines.

(d) *Approval of welders.* There is no mandatory approval of welders.

(e) *Fabrication.* To be in accordance with the French regulations.

49. There is no French system of continuing approval, each boiler or pressure vessel must be individually submitted to a hydraulic test supervised by the Service des Mines in the area where the boiler or pressure vessel is to be installed. However, the fact that the Service des Mines stamps a piece of equipment does not in any way diminish the manufacturer's responsibility for its safety.

Italy

50. Inspection and approval is compulsory by law in accordance with Standards issued by the Associazione Nazionale per il Controllo della Combustione (ANCC) which is the Government organisation responsible for the inspection and approval of all boilers imported into Italy. Where the product of the pressure (in atmospheres) and the volume (in litres) is greater than 8000 or where the maximum allowable pressure exceeds eight atmospheres, all interim inspections, the final interior inspection and the hydraulic test are all carried out in the UK by ANCC inspectors while the vessel is under construction. Where the product of the pressure (in atmospheres) and the volume (in litres) does not exceed 8000 and where the maximum allowable pressure

does not exceed eight atmospheres, the vessel is subject only to final interior inspection and hydraulic test, which may be carried out in Italy. There is no mandatory approval of works but a certificate of approval of welding procedure and welders is required. Certificates issued by certain British organisations are acceptable.

USSR

51. All steam boilers working at a pressure greater than 0·7 kg/cm^2 are subject to detailed legislation. All boilers are subject to inspection during construction, whereby the Boiler Inspectorate undertakes technical verification of the construction, in conformity with the special instructions of the Central Boiler Inspectorate. In the case of boilers not constructed within the boundaries of the USSR it is a requirement that a steam boiler shall only be taken into service after receipt of an authorisation from the Boiler Inspectorate, and that it shall have been examined by an inspector of the Boiler Inspectorate.

General summary on requirements abroad

52. Certain countries will accept pressure vessels constructed to the standards of the exporting country. Some of these are small countries which do not have their own design standards, but certain larger countries will accept plant designed to British Standards, some subject to the final documentation being authenticated by Notary Public, Chamber of Commerce or Consulate.

53. Other countries have their own rules which have been based on British practice, e.g. Australia and New Zealand. In this case submission of manufacturing drawings to the appropriate district authority is required before construction is commenced; no special authentication is however required on completion. India and Pakistan fall in a similar category regarding their Rules, but at least one UK inspection organisation is empowered to issue the required documents without specific reference to the importing country in each case.

54. In other cases strict compliance with the importing countries' own rules are required. These include the USA, Canada, Germany, Poland etc., but by reciprocal agreement at least one UK inspection organisation may carry out certain inspections and prepare and/or countersign documentation.

55. Further details of the statutory requirements abroad are given in the Technical Digests issued by the 'Technical Help to Exporters' Section of BSI, Hemel Hempstead, UK. There are also available Digests covering a large number of countries other than those considered in this appendix.

APPENDIX S

Insurance

1. There is no statutory requirement in the UK to insure pressure vessels either as such or as an integral part of a plant. Insurance is a commercial arrangement quite distinct from either technical considerations or statutory requirements. The pre-commissioning inspection undertaken on behalf of the customer is independent from any subsequent insurance of the plant concerned. Indeed, as insurance of pressure vessels in service is optional, many items of plant are operated solely on an 'inspection only' basis.

2. However, because of the requirement for inspection under the Factories Act, many pressure vessels are covered by combined inspection and insurance contracts. Inspection prior to purchase or during construction is not a condition of such insurance. Certain vessels, particularly those forming part of a comprehensive industrial plant, are insured under fire policies where there is no inspection warranty and their inspection during service will depend on their position relative to the Factories Act.

3. The standard pressure vessel insurance policy covers explosion and collapse of the vessel specified and damage to surrounding property, third party property and legal liability for third party personal injuries, and can be extended to include general damage. An inspection clause which specifically contracts to supply the inspections required by legislation is included by insurance companies in the UK. This inspection warranty clause can be waived in the case of unfired pressure vessels (ie other than steam boilers) to provide cover against explosion under a fire policy.

4. From the viewpoint of the user, however, whilst unfired pressure vessels can be covered by insuring on normal fire and explosion risk policies like any other plant, this form of policy does not cover explosions due to steam. The Factories Acts are primarily concerned with the avoidance of an explosion caused by steam, and the statutory requirements for periodic examinations of steam-raising pressure vessels may lead users to insure such equipment whilst there is no legal requirement so to insure. If cover is required for steam-raising vessels, insurance companies are usually prepared to insure vessels involved in this risk, but normally under a separate policy which effectively contracts the work involved in the statutory examinations for their own inspection staff, in consequence of which other competent inspection authorities are excluded from such work. Users expressed the opinion that it would be desirable if the distinction between steam vessels and other process vessels could be removed, and a single cover under a unified fire and explosion policy for both fired and unfired vessels were to be made available. This would help to remove such insurance problems as the steam-jacketed vessel where on one side the vessel is a process vessel and on the other side a steam vessel. Thus, it is argued that whilst periodic examination of some categories of pressure vessels is a legal requirement, the use of insurance companies' inspectors for this purpose is not a legal requirement and this should not be made a condition under which the insurance cover is issued in the UK. In this respect the UK insurance companies are normally willing to provide insurance cover under fire and explosion policies for both fired (steam) and unfired (process) vessels without differentiation where such equipment is installed *abroad*.

5. The premium charged for the insurance of a pressure vessel consists of:

(a) The inspection costs involved;

(b) The pure insurance cost as determined from experience.

(a) and (b) have no connection, and a plant owner may take out an inspection contract (without insurance) for which the charge under (a) only applies.

6. A normal prerequisite of the insurance of a pressure vessel is that adequate inspection has been undertaken (this need not include inspection during fabrication). Insurance premiums are not in themselves considered in determining design or manufacturing methods. Furthermore, loading of premiums usually depends upon abnormal working risks or service conditions and not on inspection during manufacture.

7. An insurance company confirmed that the insurance premium charged for similar sized pressure vessels in similar situations would be the same whatever design standard had been used for their construction, provided that the vessel had been certified as suitable for the use to which it was being put by a competent authority. The certification would be based on the vessel's condition as found by inspection and calculation of the safe working pressure, using the scantlings measured at the examination and taking into account the standards of construction used together with any special conditions of working. This could be taken to imply that a vessel with a wall thickness based on UTS/2·35 or UTS/2·7 (BS 1515 and ISO) would be charged the same insurance premium as a vessel identical in all respects but with a thinner wall based on YS/1·5 (TUV Standard). The continued use in the UK of UTS as a factor to determine the vessel wall thickness does not appear therefore to be dependent upon either availability of insurance coverage or a preferential insurance premium rate in the UK.

8. The anticipated life of equipment for chemical plant and oil refineries in the UK is normally accepted by convention as 25 years, but in practice this may be considerably shorter. The 25 year plant life is longer than that required by American and some Continental users. The length of life of a vessel has no bearing on the insurance premium charged (according to an insurance company), as insurance policies are designed to afford compensation for sudden and unexpected accidents.

9. It was also commented that in some countries abroad the insurance companies are separate from inspection arrangements, and that the inspection authorities are independent and non-profit making. Foreign insurance companies apparently issue suitable insurance cover but do not take part in certification, inspection, or in any decisions regarding fabrication or safety of plant. In America the Inspectorate, by virtue of their State Licences, are supported by law. The Inspectors, although engaged by insurance companies in many instances, submit copies of their reports to the State Authorities in all instances, and this results in a combination of private and Government supervision.

APPENDIX T

UK activities relating to pressure vessels

1. The present appendix lists very briefly a selection of organisations and their respective activities relating to the topic of pressure vessels in the UK. The list is not exhaustive; it is intended to indicate the variety of activities that relate to pressure vessels rather than to provide for completeness.

2. There is a bewildering variety of BSI working Committees involved in pressure vessel work of one type or another. These report in turn to a number of main Industrial Committees. As an indication of the variety of Standards that are produced, the following list indicates that over 100 refer to pressure vessels, boilers, gas cylinders, pipes, welding, materials and test standards (the list does not include standards on other related topics, eg heat exchangers and tanks):

Pressure Vessels (BS 1500, 1515, 1966, 3463)

Pressure Vessels for Nuclear Reactors (BS 3915)

Boilers (BS 609, 761, 854–5, 931, 1113, 1307, 2790, 3128)

Sterilizers (BS 2904, 3213, 3219, 3220, 3233)

Air Receivers (BS 428–30, 487, 1099, 1123)

Air Reservoirs (BS 3256)

Gas Cylinders (BS 341, 349, 399–401, 1045, 1287–8, 1319)

Pipes (BS 378, 778, 1387, 1627–8, 3014, 3059, 3601–5, 3889, 3923)

Pipe Fittings (BS 1387, 1560, 1640, 1965, 3439, 3581, 3799)

Pipe Flanges (BS 1560, 1575–6, 3063, 3293, 3381)

Welding (BS 693, 1126, 1453, 1821, 1856, 2633, 2640, 2642, 2901, 2937, 2971, 3019, 3571)

Materials for Pressure Vessels and Boilers (BS 14, 1501–6, 1510, 1633, 3740)

Test Standards:
  for Boilers (BS 845, 2455, 2885)
  for Pipes (BS 3889)
  for Welding (BS 709, 1138, 1140, 3451)
  for Welders (BS 1295, 2645)
  for Materials (BS 18, 131, 240, 427, 891, 1094, 1639, 3228, 3500, 3518, 3688, 3920)
  for Radiographic Examination (BS 499, 2600, 2737, 2910, 3513)
  for Ultrasonic Examination (BS 3889, 3923)

3. In an endeavour to co-ordinate the work at BSI a Pressure Vessel Standards Committee E/–/3 was set up in 1966 with three Sub-Committees working under its authority (which is, it is understood, of a purely advisory nature):

E/–/3/1	International Work on Pressure Vessels;
E/–/3/2	Co-ordination and Approach to the Design, Manufacture and Testing of Pressure Vessels;
E/–/3/3	Materials of Construction and Associated Welding Procedure

Several Working Parties and Task Groups have been set up by the E/–/3/2 Committee to prepare specific proposals in selected areas (eg 'Task Group on Manufacture, Workmanship, Inspection and Testing').

4. A further problem relating to standards for pressure vessels is the decision of the UK to metricate. All the BS for pressure vessels will be converted to metric units, although it is understood this will not be a difficult task except for flange design.

5. Discussions on pressure vessels have been organised by the Institution of Mechanical Engineers, the Welding Institute and the West of Scotland Iron and Steel Institute. The first-named publishes many papers on the subject, and through the Engineering Sciences Data Unit, produces design memoranda.

6. There is no single research centre for work on pressure vessels, although the BWRA (now the Welding Institute) has worked extensively in this field particularly on weld behaviour. The CEGB, as an extensive user of boilers and pressure vessels, has contributed towards the establishment of the Power Engineering Research Steering Committee, between the electricity supply side and manufacturers, in order specifically to review the adequacy of research in this field and to encourage collaborative research programmes.

7. Support for research work at academic institutions is provided by the Science Research Council; support for industrial development of welding techniques and of new materials with good welding qualities may be considered for support by the Ministry of Technology.

8. The Ministry of Technology's Process Plant Branch acts as a focal point for the process plant and fabrication industries for liaison between Government and the industry. The Ministry's Standards Division acts as a focal point for matters relating to standards, standardisation, metrication, quality assurance and associated topics.

9. The NEDC has the following two bodies reporting to it on, inter alia, market demand trends and current supply data relating to fabricated vessels:

(a) Mechanical Engineering Economic Development Committee (whose quarterly 'Short Term Trends' reports indicate the orders and deliveries position for water tube boilers, shell boilers, chemical and other plant etc.);

(b) Process Plant Working Party (who have published three reports, the first dated January 1967, dealing largely with the future demand for process plant).

10. Other Committees currently working in the field of pressure vessels are:

(a) Committee on Gas Cylinders (of the Home Office) which has completed a detailed Report towards improvement of the methods of manufacture, test and inspection of all types for pressure vessel intended for conveyance by road;

(b) Working Party on Technical Computer Applications to the Pressure Vessel Industry, of the National Computing Centre (this is described in Appendix O).

APPENDIX U

International activities relating to pressure vessels

1. The present appendix lists very briefly a selection of organisations and their respective activities relating to the topic of pressure vessels internationally. The list is not exhaustive, it is intended to indicate the several lines along which pressure vessel activities are proceeding rather than to provide for completeness.

International Standards Organisation (ISO)

2. ISO/TC11 is the Committee responsible for the Unification of the Rules for Construction of Boilers, and from the early 1950's until 1965 its work was concerned with the preparation of the ISO Boiler Code—ISO Draft Recommendation No. 851—Rules for Construction of Stationary Boilers—which was circulated in 1965 to all ISO member bodies for postal ballot.

3. In June 1966, the ISO Council approved the following new scope and title for ISO/TC11:

Title: Boilers and Pressure Vessels;

Scope: Standardisation and securing international co-ordination of:

(a) Design and construction of safe boilers (stationary) and pressure vessels;

(b) Methods of inspection and testing of such boilers and vessels;

(c) Material requirements for the component parts used in the construction of such boilers and pressure vessels.

4. Three Sub-Committees have been set up as follows:

ISO/TC11/SC1: Materials for Boilers
(Secretariat: Germany)

ISO/TC11/SC2: Strength of Pressure Parts
(Secretariat: France)

ISO/TC11/SC3: Workmanship and Construction—Welding
(Secretariat: Netherlands)

5. A plenary meeting of ISO/TC11 was held in October 1967, which reviewed drafts prepared by the Sub-Committees, and the various activities of the Sub-Committees were co-ordinated in an endeavour to produce a complete first draft pressure vessel Recommendation. Whilst a complete first draft was not forthcoming from the plenary meeting, a 'vote of confidence' was given to the Secretariat (the USA) to proceed with the preparation of a 'draft of a first draft proposal' based on the documents notionally approved at the meeting.

6. ISO/TC17/WG10 is the working group set up in 1964 to draft proposals for 'Steels for Pressure Vessels', by developing specification documents for the individual types and grades of carbon and alloy steels on a basis consistent with the requirements set out by ISO/TC11/SC1 (which would continue to define in general terms the essential requirements for steels from the standpoint of the intended usage).

7. ISO/TC58/SC3 is the Sub-Committee on Gas Cylinder Design (Secretariat: Netherlands) which has been preparing proposals on the design, construction and acceptance of both seamless steel and welded steel cylinders.

8. ISO/TC85/SC3/WG6 is the Working Group on Steel Nuclear Pressure Vessels (Secretariat: Germany) and sub-groups have been set up to prepare drafts for materials for design, and for manufacture and testing. The UK is the co-ordinating body for the Sub-Group on design and has already submitted a draft based on Section 3 of BS 3915.

European Standards Co-ordinating Committee (CEN)

9. CEN/WG23/SG1 is the sub-group for gas cylinders (Secretariat: UK); in respect of container design the sub-group is awaiting the ISO proposals.

10. CEN/WG23/SG2 is the sub-group for type-tested, welded, air receivers (Secretariat: Sweden) and a draft CEN-Code has been completed, based on a PNEUROP proposal in which is used the ISO draft boiler rules for design (but with no factor on UTS for computing the nominal design stress) and the manufacturing and testing sections are similar to the Baumeisterprufung Rules.

11. CEN/WG23/SG3 is the sub-group on other unfired pressure vessels (Secretariat: UK) which has recently started work.

12. CEN/WG42 is the working group to consider the harmonisation of the administrative requirements involved in operating a reciprocal approvals scheme by European countries. The need for this arises owing to the different rules and regulations on approval, inspection and acceptance of equipment in force in these countries. The working group is considering, as a pilot scheme, the approval and acceptance procedures of CEN type-tested welded air receivers (CEN/WG23/SG2).

European Economic Community (EEC)

13. The EEC has issued a proposed General Directive specifying inspection and approval procedures for member countries, together with proposed rules for approving inspection authorities, and proposals for an EEC inspection approvals stamp. The 'Proposed general directive on the approximation of the laws of the member states concerning pressure vessels' appears to make no provision for reciprocal arrangements outside EEC.

European Free Trade Area (EFTA)

14. The EFTA countries have made no proposals similar to those of EEC above, but in 1967 the EFTA Secretariat circulated proposals prepared by the Syndicat de l'Industrie Européenne des Bouteilles à Gaz Soudées (SEBS) for the harmonisation the regulations regarding safety and pre-delivery tests of welded gas cylinders.

15. As the incorporation of ISO and other internationally agreed Standards Recommendations into national standards is not mandatory, the following recommendation was endorsed by the EFTA Council of Ministers in Bergen (May 1966):

> 'The national standards bodies should be pressed to make the strongest efforts to secure a full acceptance of the results of international standards agreements without deviation and public purchasing departments should be urged to take full account of such standards'.

Other organisations

16. Colloque Européen des Organismes de Contrôle—CEOC (the Association of European Inspection Organisations) is directly concerned with the inspection of pressure vessels, being an association of certain (but not all) of the various European inspection organisations. One of its aims is:

> 'the establishment of recommendations concerning pressure vessels and installations, subject to inspection and control, which may be the subject of consideration by national authorities in each of the member countries with a view to possible modifications of the national regulations'.

17. Syndicat Européen de Réservoirs à Gas Soudés, is an organisation made up of Continental European fabricators (no UK membership) of pressure vessels up to 5,000 litre water capacity, and the organisation works towards further standardisation.

18. Comité Européen de la Chaudronnerie et de la Tôlerie (CECT), which is an association of national trade associations for the pressure vessel industry, is concerned with the co-ordination of national efforts in standards and inspection practice and other topics. It has members in the six countries of EEC and the seven countries of EFTA.

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Appendices of Evidence
Submitted to the Committee
under the Chairmanship of
Mr. R. W. Nichols

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Members of the Committee

Mr. R. W. Nichols (*Chairman*), B Met(Hons), FIM, M Inst W; (Deputy Head, UKAEA, Reactor Materials Laboratory)

Mr. A. H. Goodger, MSc Tech, FIM, FRIC, F Inst W; (Consultant, formerly Technical Chief of the National Boiler and General Insurance Co.)

Dr. K. J. Irvine, BSc, PhD; (Metallurgical Research Manager, United Steel Companies Ltd.)

Professor W. R. D. Manning, MA, C Eng, FI Mech E, MI Chem E; (Consultant and Visiting Professor to Loughborough University of Technology)

Professor J. L. M. Morrison, CBE, DSc, C Eng, FI Mech E; (Professor of Mechanical Engineering, Bristol University and Vice President of the Institution of Mechanical Engineers)

Mr. M. J. Noone, OBE, C Eng, FI Mech E, MI Chem E, MI Gas E, F Inst Pet; (Group Chief Executive, Whessoe)

Dr. P. J. Palmer, DSc, PhD, MSc, DIC, ARCS, C Eng, FI Mech E, AFRAeS, A Inst P, M Inst W, MBIM, Mem ASME; (Managing Director, BOC-AIRCO)

Mr. L. F. Robinson, AMICE, AI Arb; (Managing Director, Power-Gas Corp. Ltd.)

Mr. C. S. Tanner, BSc, MSc, C Eng, FI Mech E; (Consultant, formerly Engineering Manager, Agricultural Division, ICI Ltd.)

Joint Secretaries: Mr. J. S. Linton, C Eng, MI Mech E, AFRAeS; (Ministry of Technology)

Dr. H. J. Ivey, BSc, PhD, C Eng, MI Mech E, FBIS; (Ministry of Technology)

MINISTRY OF TECHNOLOGY
Millbank Tower
Millbank
London, SW1

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- D. Subject index

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